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VOL. 1 SEPTEMBER 1914 No. 3

DISINFECTING 200,000,000 GALLONS OF WATER A DAY—EXPERIENCE WITH CHLORIDE OF LIME AND LIQUID CHLORINE AT TORRESDALE FILTRATION PLANT

By Francis D. West

In a paper presented before the annual convention of the New Eng and Water Works Association, September 10, 1913 ("Torresdale Filter Plant Methods and Results 1907–1913" by Francis D. West, Chemist in charge Torresdale Laboratory and Joseph S. V. Siddons, Superintendent Torresdale Filters, (*Journal N. E. W. W. A.*, vol. 27, no. 3, September, 1913), a general summary of the results obtained with the use of calcium hypochlorite was given.

The following article goes into detail and includes the results obtained with liquid chlorine November 26, 1913, to date; together with certain data on liquid chlorine gathered from other sources.

Historical Sketch of Disinfection at Torresdale

ELECTROLYTIC SODIUM HYPOCHLORITE

Bleach was first used at Torresdale in the form of hypochlorite of soda produced electrolytically during September, 1909.

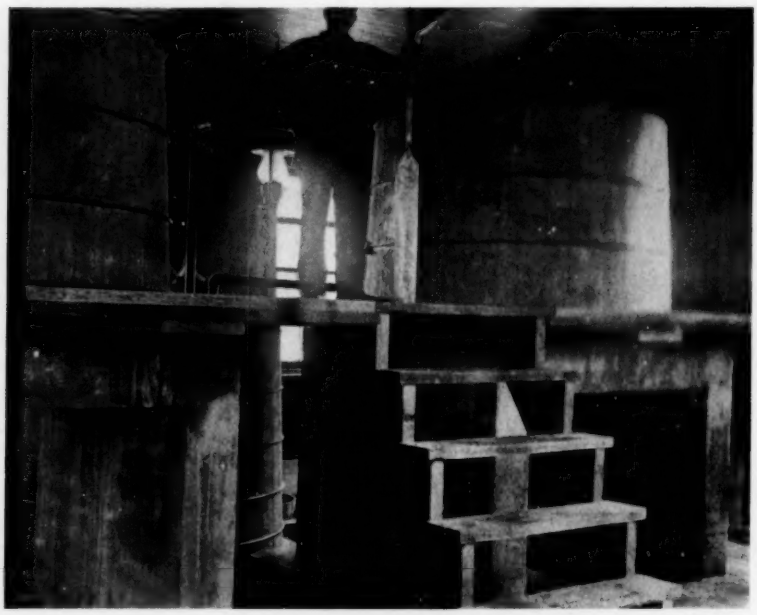
Two cells were used. A current of 35 amperes at 110 volts was used to decompose a brine solution. The chlorine and soda were allowed to recombine and the temperature was so high (about 110° F.) that chlorates were formed. The bleach was applied directly in front of the inlet valve of one of the preliminary filters operated at a 20 M. G. P. D. rate or about one-fourth normal.

The conclusions were in part that the bacterial efficiency of the

filter was considerably less than that of filters operated at four times the rate without treatment.

CALCIUM HYPOCHLORITE

Hypochlorite was again used in December, 1910. Due to the fact that the bacterial efficiency of slow sand filters decreases considerably in cold weather and the fæcal organism B. Coli Communis was present in the filtered water, it was decided to use chloride of lime to disinfect the water in the filtered water basin.



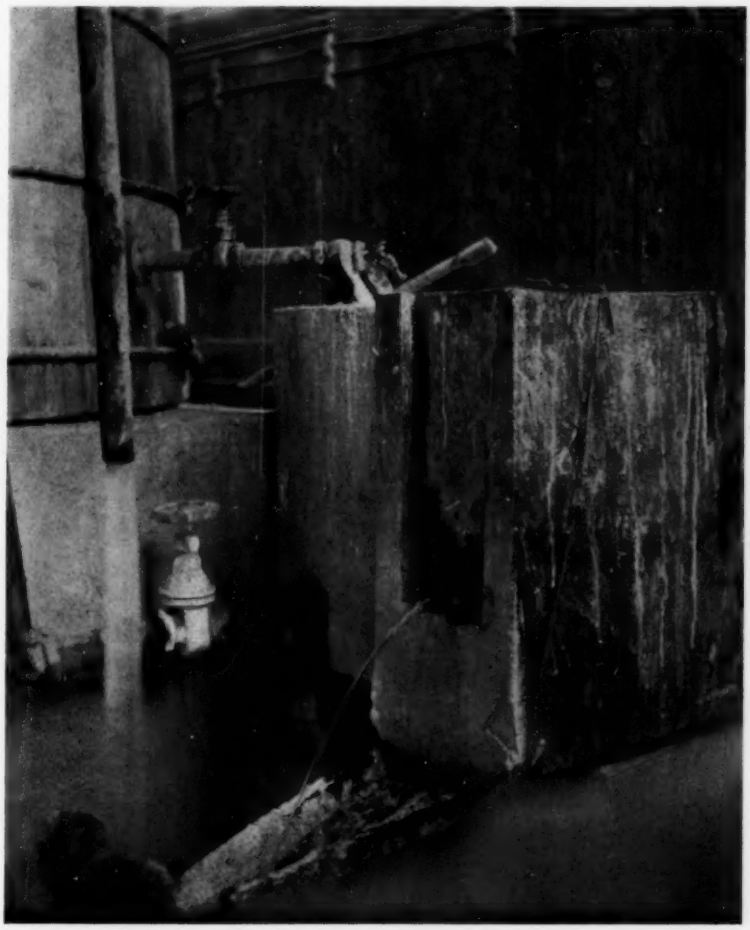
No. 1. Torresdale Hypochlorite Plant Mixing and Solution Tanks

Treatment was continued until April, 1911, when it was stopped until December. Treatment was again started December, 1911, and was continued without interruption until February, 1913.

LIQUID CHLORINE

This was first used November 26, 1913, in conjunction with chloride of lime, about 90 pounds liquid and 800 pounds powder being used daily until February 9, when the use of chloride of lime was stopped.

Description of bleach plant. The plant at first consisted of two cedar mixing tanks each 5 feet in diameter and 4 feet deep and one solution tank of the same dimensions, capacity about 500 gallons; and a yellow pine orifice tank cubical in shape, 2 feet on a side. This tank was soon changed to a concrete tank of the same dimensions.



No. 2. Torresdale Hypochlorite Plant Orifice Tank

After five months' continuous use the tanks became so badly perforated that they could no longer be used. They were replaced by new tanks which were later lined with 3 inches of cement. The capacity was reduced to 380 gallons.

Cut No. 1 shows the mixing and solution tanks and cut No. 2 shows the orifice tank.

Mixing. This was done by hand by two laborers using paddles, each mix receiving about two hours agitation.

Cost. The cost of installation of the chloride of lime plant amounted to $815 (this does not include the tanks purchased later) and the cost of operation for the first five months was 9 cents per million gallons.

The cost for 1912 was 9 cents and for 1913 11 cents per million gallons.

No charge is allowed for time of sample collector or services of chemist.

From two to six mixes were made a day, usually three, using 500 and later 380 gallons of water per mix.

Analytical tests. Tests were made of samples of powder, of solution and of sludge, giving a close check on how well the bleach was mixed.

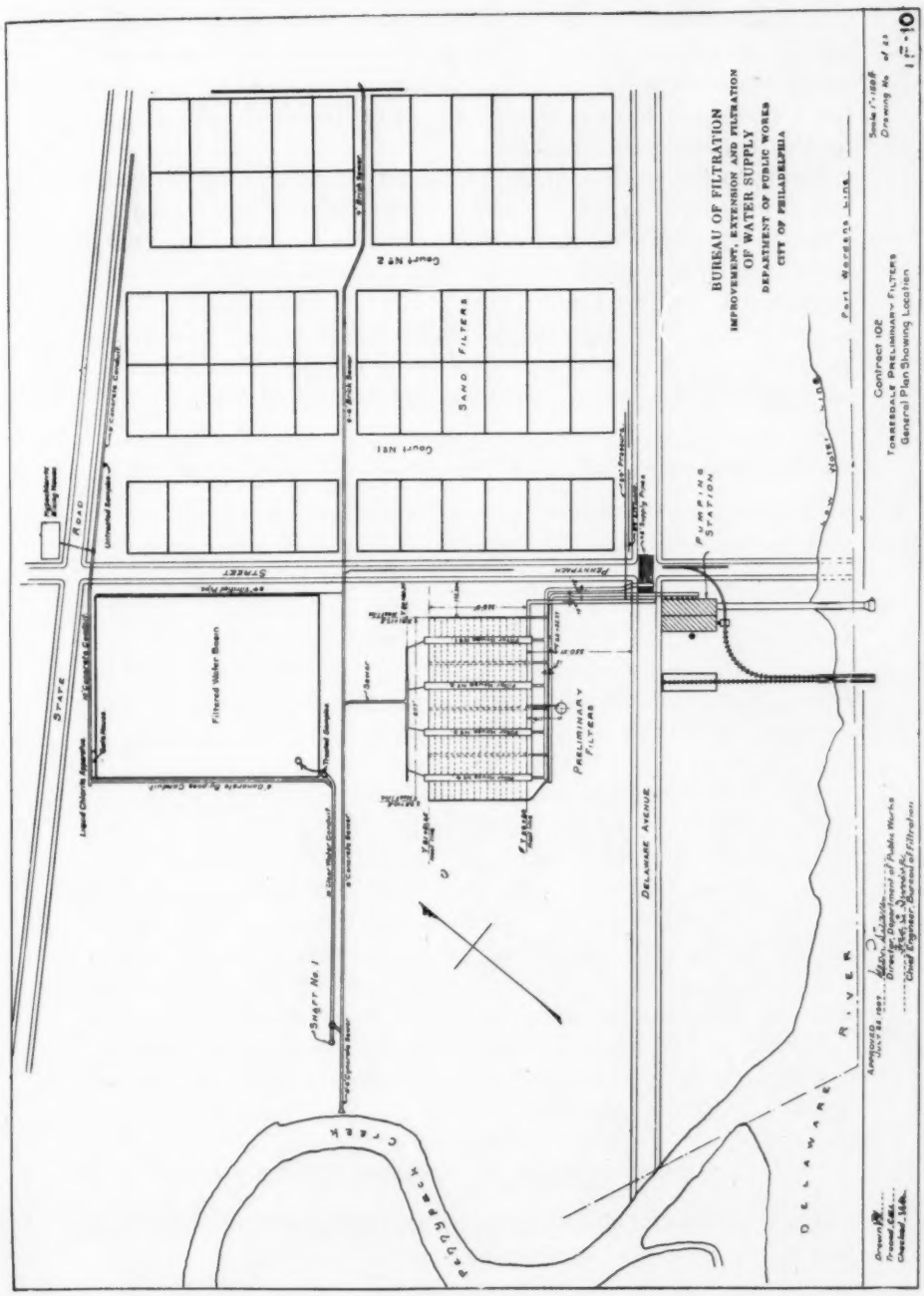
Table I shows the quantities of powder and strength of solutions used at different periods. The maximum amount was 3480 pounds per day and the minimum 420 pounds.

TABLE I

A	B	C	D	E	F	G
420	36.0	151	10.1	3.6	0.28	0.10
540		194	13.0	4.7	0.36	0.13
600		216	14.4	5.2	0.40	0.14
800		288	19.2	6.9	0.53	0.19
1,200		433	28.9	10.4	0.80	0.29
1,600		577			1.07	0.38
2,000		720			1.33	0.48
2,400		864			1.60	0.58
3,200		1,154			2.13	0.77
3,480		1,255			2.32	0.84

A = pounds powder per day.
B = Average available chlorine in bleach.
C = Pounds available chlorine per day.
D = Per cent of powder in solution tank at 500 gallons.
E = Per cent available chlorine in solution tank.
F = Parts per million powder in filtered water basin at 180,000,000 gallons per day.
G = Parts per millions available chlorine in ditto.

The amount of available chlorine wasted in sludge has varied from 0.1 to 7 per cent and averaged about 1 per cent.



No. 3. Plan of Torresdale Filter Plant Showing Location of Hypochlorite and Liquid Chlorine Plants

Location of bleach p'ant. This plant is located between the slow sand filters and the filtered water basin. The solution was fed into an air vent in the filtered water conduit. The water at this point has a velocity of 4–5 sec. ft. (See plan of Torresdale Filter Plant for location of Bleach House.)

Owing to the location of the plant and the velocity of the water it was impossible to get a sample of the combined effluents of the filters before treatment and as a consequence we have been unable to tell exactly how much work the hypo has been doing. (Recently, January 19, 1914, we made a vent in the filtered water condu't and placed in it a 4-inch pipe into which we lower our collecting device to get samples of filtered, untreated water.)

The following table (II) shows the results of treatment.

Note. Tap at Lardner's Point pumping station shows the condition of the water after passing through a 3-mile conduit 100 feet under ground.

By examining the results for May–November, 1911, it will be seen that the average number of bacteria in the filtered water basin during this period was but 35 per cubic centimeter. (Omitting November it was only 19.) The per cent of positive tests in summer was very high. In July for 10 cc. with a count of 9, 48 per cent were positive, and for June with 14 bacteria 51 per cent were positive. During November, due to temperature changes the bacteria efficiency decreased materially and the basin had an average of 120 with B. coli present in 1 cc. 13 days out of 30.

The effect of starting treatment in December is very noticeable. The use of $\frac{1}{2}$ to 1 part per million of powder, while it did not keep the count low during the spring of 1912 did nearly eliminate B. coli from the water that had passed the filters. The low count and lack of sufficient bleach caused the department to use $\frac{1}{4}$ to $\frac{1}{3}$ part of powder during the summer and as a consequence the per cent of positive tests in 10 cc. again went up reaching 34 per cent with a count of 13 in June and 26 per cent with a count of only 7 in August.

During 1913 $\frac{1}{2}$ part or more of powder was used all year and as a consequence the per cent of positive tests for the basin was but 1.4 for 1 cc. and 8.5 for 10 cc.

DISADVANTAGES OF CHLORIDE OF LIME

There are several objections to the use of hypochlorite of calcium and to our method of applying it.

TABLE II

Showing average bacteria count and number of positive tests for B. Coli Communis in Torresdale filtered water basin and tap at Lardner's Point pumping station 1911–1913 inclusive

	FILTERED WATER BASIN				LARDNER'S POINT PUMPING STATION			
MONTH	Number tests	Aver. bact. per cc.	B. Coli		Number tests	Aver. bact. per cc.	B. Coli	
			1 cc.	10 cc.			1 cc.	10 cc.
1911								
January	31	25	1	5	26	20	1	2
February	28	11	4	4	23	12	1	1
March	31	7	1	2	27	7	0	3
April	30	10	0	1	24	12	0	3
May	31	14	1	12	26	11	1	10
June	30	29	2	14	26	24	3	8
July	31	9	3	15	25	20	0	8
August	31	14	3	16	27	14	1	12
September	30	29	3	20	25	21	2	13
October	31	20	6	22	26	20	2	17
November	30	120	13	24	24	98	9	19
December	31	15	0	8	24	13	1	6
Total	365	0	37	143	303	0	21	102
Average		25				23		
Per cent positive			10.1	39.2			6.9	33.7
Jan.-April and Dec.	151	14	6	20	124	13	3	15
Per cent positive			4	13.3			2.4	12.4
May-Nov. inc	214	35	31	123	179	30	18	87
Per cent positive			14.5	58			10	48.6

January-April and December treated; May-November untreated.

TABLE II—Continued

MONTH	FILTERED WATER BASIN				LARDNER'S POINT PUMPING STATION			
	Number tests	Aver. bact. per cc.	B. Coli		Number tests	Aver. bact. per cc.	B. Coli	
			1 cc.	10 cc.			1 cc.	10 cc.
1912								
January	31	30	1	2	26	21	0	1
February	29	250	1	7	23	98	1	3
March	31	99	1	6	25	110	0	4
April	30	22	0	3	25	20	0	1
May	31	17	1	2	26	14	0	3
June	29	13	2	10	24	19	1	9
July	31	7	2	5	26	8	1	4
August	31	7	0	8	26	6	0	2
September	30	10	2	10	24	8	1	6
October	31	15	2	10	27	13	1	5
November	29	17	1	12	23	22	0	9
December	31	15	2	5	25	19	1	3
Total	364		15	80	300		6	50
Average		44				30		
Per cent positive			4.1	22			2	16.9
Per cent positive when more ½ P. was used			2.5	14.9			1.1	9.1
1913								
January	31	23	1	5	26	20	1	4
February	28	6	0	0	22	5	0	1
March	31	11	1	1	24	9	0	0

1913								
April	30	10	0	0	26	9	0	1
May	31	5	0	0	26	4	0	0
June	30	5	0	0	25	4	0	0
July	31	4	0	2	26	5	0	4
August	31	6	0	3	26	9	1	5
September	30	5	1	7	25	6	1	10
October	31	13	1	7	27	14	0	5
November	30	31	1	4	23	30	0	5
December	31	30	0	8	31	17	0	0
Total	365		5	31	301		3	35
Average		13				11		
Per cent positive			1.4	8.5			1	11.6

First: Variation in strength of solution. This is due chiefly to three things:

(a) The quantity of available chlorine in the powder has varied from 21 per cent to 43 per cent.

(b) The readiness with which the bleach mixes with water.

The writer has seen two batches of equal strength, one of which mixed readily with little sludge and the other forming lumps seemingly impossible to break up.

(c) Hand mixing of 400 pounds in 388 gallons of water.

It is not reasonable to expect that this can be done thoroughly by hand. In fact the tanks are allowed to stand for different periods of time and the one in contact with water longest has the greatest strength.

Second: Interruption to feed of solution. This may be caused, as happened, by one of three things:

(a) Corroding of orifice, decreasing the amount of flow;

(b) Stopping of orifice by lumps of sludge, and

(c) Choking up of delivery pipe.

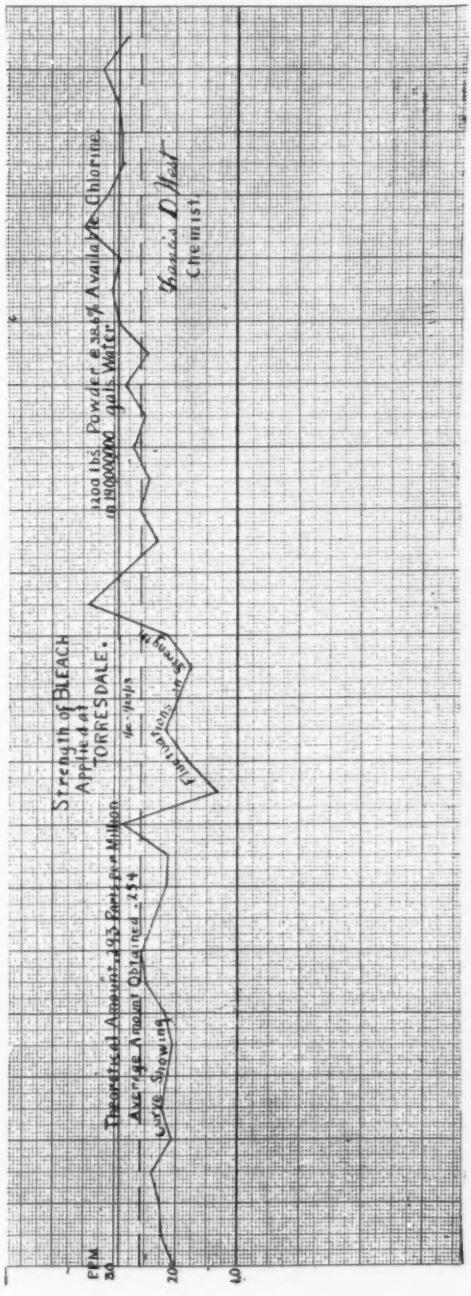
Third. Tastes and Odors. This has been in all probability the most serious objection of any at other places although we did not have many complaints. When we used over 2400 pounds per day some complaints were made.

The chart shows the variation in strength of solution from a lot of bleach which had apparently a consistent amount of available chlorine.

It also shows how much below the theoretical amount was the quantity actually obtained from the powder.

Under the most advantageous conditions we were able to get but an average of .25 parts per million out of a theoretical amount of .293 parts or only 87 per cent of what we should have gotten.

Allowing then a general average of 36 per cent of available chlorine in the powder we obtained but 31 per cent. This was with cans which were used as soon as opened. When a can is allowed to stand exposed even for a day a material loss takes place. A figure of 30 per cent available chlorine is then a high estimate of the amount gotten out of powder in practice; ordinarily with careless mixing, with no tests of powder or solutions and after exposure for days as usually happens 25 per cent may be stated as the amount the average operator will add to the water.



No. 4. Chart Showing Variation in Strength of Solution of Bleach

In considering the Chart it may be noted that .6 per cent chlorine was thrown away in sludge.

The following table (III) shows the amounts of chloride of lime used during 1912 and 1913.

TABLE III

Monthly averages available chlorine in powder

MONTH	PER CENT OF AVAILABLE CHLORINE	
	1912	1913
January	35.1	37.4
February	37.0	40.6
March	37.2	39.1
April	36.5	36.3
May	33.3	38.1
June	32.3	34.3
July	34.2	37.0
August	30.8	31.9
September	37.4	33.9
October	37.4	36.3
November	34.4	34.2
December	36.3	35.3
Annual average	35.2	36.2

TABLE III (a)

Monthly average parts per million powder and available chlorine used during 1913

MONTH	POWDER	CHLORINE
January	0.82	0.30
February	0.76	0.27
March	0.84	0.30
April	0.79	0.28
May	1.30	0.47
June	1.06	0.38
July	0.54	0.19
August	0.51	0.18
September	0.51	0.18
October	0.77	0.28
November	1.06	0.38
December	0.80	0.29

TABLE III (b)

Variations number of days

1912 (Calculated on 190,000,000 gallons per day)

LBS. POWDER PER DAY	NUMBER OF DAYS	PARTS PER M. POWDER	PARTS PER MILLION AVAIL. Cl. @35%
420	35	0.27	0.09
600	26	0.38	0.13
630	85	0.40	0.14
800	130	0.51	0.18
1,000	4	0.63	0.22
1,200	48	0.76	0.27
1,600	23	1.01	0.35
1,733	1	1.09	0.38
2,000	3	1.27	0.44
2,266	1	1.43	0.50
2,400	9	1.52	0.53

1913 (Calculated on 180,000,000 gallons per day)

LBS. PER DAY POWDER	LIQUID Cl.	NUMBER OF DAYS	PARTS PER M. POWDER	PARTS PER MILLION AVAIL. Cl. @36%
800		92	0.53	0.19
800	+ 90	14	0.53	0.25
800	+ 105	13	0.53	0.26
1,200		131	0.80	0.29
1,200	+ 10	1	0.80	0.30
1,200	+ 90	4	0.80	0.34
1,600		73	1.07	0.38
1,600	+ 90	4	1.07	0.41
2,000		15	1.33	0.48
2,400		14	1.60	0.58
3,360		3	2.25	0.81
3,480		1	2.32	0.84

HISTORICAL SKETCH OF USE OF LIQUID CHLORINE IN UNITED STATES FOR THE STERILIZATION OF WATER

The credit for the introduction of liquid chlorine for water disinfection belongs to Major C. R. Darnell, U. S. A.

He first tried it in June, 1910. In November, 1911, he published in the *Journal of the American Public Health Association* under the title of "The Purification of Water by Anhydrous Chlorine," a description of his apparatus together with the results of his experi-

ments. He applied the chlorine in the form of a dry gas to the water to be treated.

Major Darnell carried out a series of tests with an apparatus with the capacity of 500 gallons per hour.

The Board of Officers of the War Department concluded (June, 1911,)

"That the apparatus is as efficient as purification by ozone or hypochlorite and is more reliable in operation than either.

"That it could be installed at a very low cost and that the cost of operation would be very slight."

In June, 1912, Dr. Geo. Ornstein constructed an experimental apparatus for the use of chlorine gas for water and sewage sterilization, employing an entirely different principle from Major Darnell, involving the absorption of the gas in water prior to its application to the fluid to be treated.

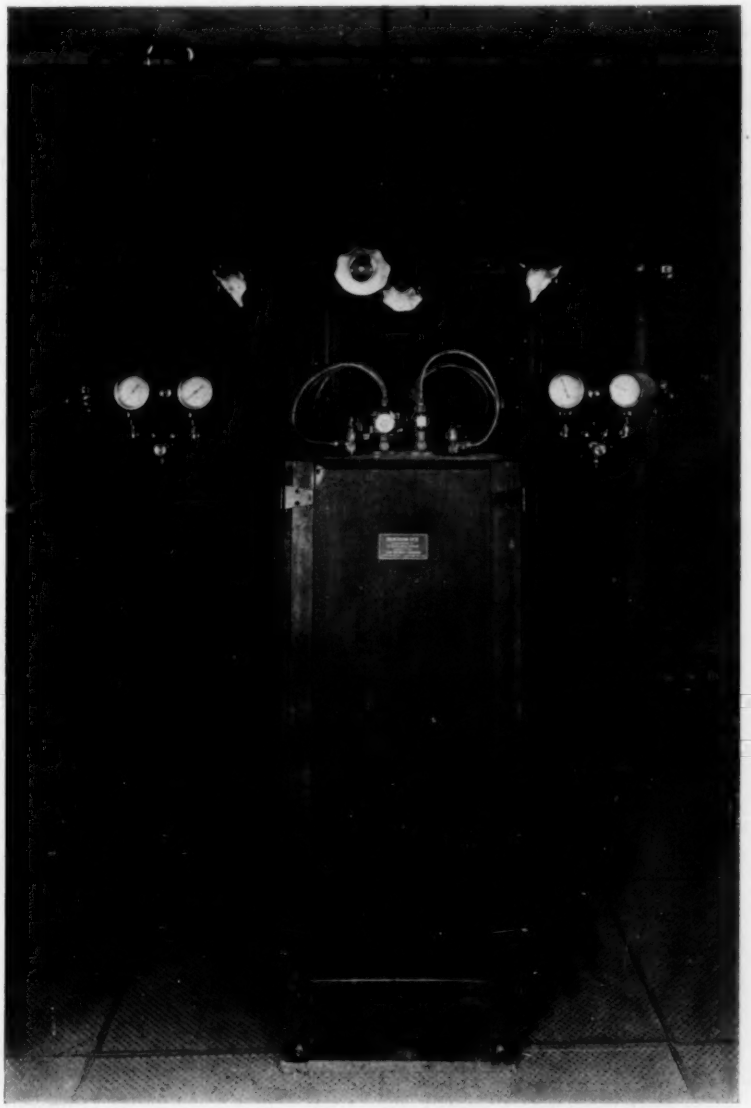
In September, 1912, Mr. Seth M. Van Loan, assistant chief engineer Philadelphia Bureau of Water, assisted by Dr. Geo. E. Thomas, chemist Belmont Laboratory, experimented with liquid chlorine on a large scale at Belmont Filter Plant. They fed the chlorine into the filtered water basin in the form of a gas, regulating the quantity by loss in weight of the containers, 46 pounds per day being applied to 38,000,000 gallons of water.

With the approach of cold weather the difficulty of freezing was encountered. Later the cylinder was jacketed and heated by a lamp.

Early in November Mr. John A. Kienle, chief engineer of the Water Department of Wilmington, Delaware, worked along similar lines at the Wilmington Plant. By the use of high and low pressure valves he was able to regulate the flow of gas. His results were presented at the 1913 Convention of the American Water Works Association. The apparatus used by him makes use of an absorption tower, whereby the chlorine is absorbed by a small amount of flowing water which carries it into the supply to be treated.

About the same time Mr. D. D. Jackson was experimenting at Ridgewood Reservoir, Brooklyn, and shortly afterward put out the Leavitt-Jackson Liquid Chlorine Machine. This machine operates on the basis of a balanced beam, feeding the gas according to loss in weight. The gas is fed directly into the water to be treated similarly to the Darnell apparatus.

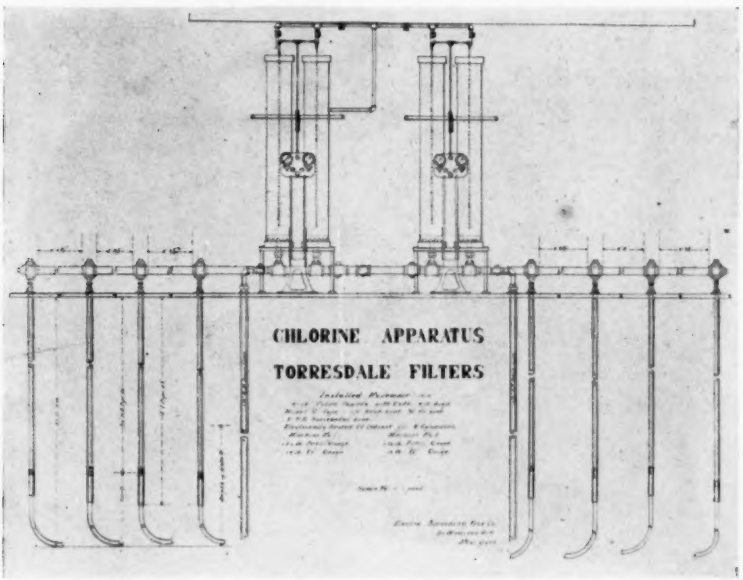
The first complete set of results for a continued period are those from the Niagara Falls Plant operated by the Western New York



No. 5. Liquid Chlorine Apparatus at Torresdale Filter Plant

Water Company under direction of Mr. H. F. Huy. (For the use of these results the author's thanks are due Mr. Huy and Mr. J. W. Ledoux.)

The first permanent Liquid Chlorine Plant in Philadelphia was installed at Queen Lane Filter Plant, September 1913. A contract for ten plants, two at each of the five filter plants, was awarded at a cost of $9750. The plants were installed during October and November, 1913; that at Torresdale starting November 25.



No. 6. Liquid Chlorine Apparatus at Torresdale—Showing Chlorine Feed Pipes

Cut No. 5 shows the present installation at Torresdale.
An elevation of the plant is shown on sketch No. 6.

LOCATION

The liquid chlorine plant is located at the inlet house of the filtered water basin (see plan of Torresdale Filter Plant).

This gate house is directly over two inlet chambers fed by a 10-foot conduit; the water enters the basin through eight 48-inch valves, four in each chamber.

GENERAL DESCRIPTION OF APPARATUS

From four to eight cylinders of liquid chlorine are connected by means of flexible copper coils to a manifold with a valve for each cylinder. The manifold is connected with a gauge used to determine initial pressure.

Beyond this gauge are two regulating valves; the first reducing the initial pressure to about 15 pounds per square inch and the second for regulating the pressure through a range sufficient to give the desired amount of gas. A low pressure gauge calibrated empirically indicates the flow of gas.

The gas then passes through a $\frac{3}{8}$-inch hard rubber pipe to the bottom of the first absorption tower. This tower is 8 feet high and is filled with coke to give surface. This tower is sealed; the excess gas passes through a second pipe to the bottom of a second tower.

These towers as well as all other parts from this point on are made of hard rubber. Water is admitted through the top of the towers.

The chlorinated water passes through a horizontal pipe 58 feet long, 4 inches in diameter connected with eight drops $\frac{3}{4}$ inch in diameter, extending to within one foot of the bottom of the chamber and protected from the current by $1\frac{1}{2}$-inch iron castings.

About three feet of flexible rubber hose is attached to the ends of these pipes. The ends of the hose are kept in motion by the swirl of the current.

ORIGINAL APPARATUS AND CHANGES THERETO

Owing to the large quantity of chlorine needed (as high as 10 pounds per hour) it was planned to feed the chlorine in liquid form through the cylinder valves having an evaporator placed next to the high pressure valve. This was done to prevent freezing owing to the reduction in temperature due to the rapid evaporation.

Cradles were provided for inverting the cylinders. The evaporator was prevented from freezing by having a constant flow of water passing around it.

From almost the start trouble was experienced. The needle and regulating valves of the apparatus gradually choked up with the impurities in the chlorine cylinders, chiefly ferric chloride. Liquid chlorine was allowed to pass through the feed pipe of the tower corroding and choking this up. Liquid chlorine found its way through the coil in the evaporator, where it came in contact with the

water used for cooling, and the whole apparatus went out of commission. (In spite of all these difficulties a supply of chlorine was kept up with but two shut downs of any consequence.)

When it was found impossible to supply the gas in this manner the cylinders were used vertically and an electrically heated cabinet with automatic thermostatic control, as shown in cut, was installed. This keeps the cylinders at a temperature of 70°F. and but little trouble with freezing is experienced.

RESULTS FROM TREATMENT AT TORRESDALE, BELMONT, UPPER AND LOWER ROXBORO, QUEEN LANE, WILMINGTON, DEL., NIAGARA FALLS, AND ELSEWHERE

Liquid Chlorine Compared with Bleach at Torresdale Filter Plant

Liquid Chlorine has only been used by itself since February 8 so that it is difficult to get figures that are exactly comparable:

It was on the following data that the estimate of a strength of 1–6 was based.

Test No. 1. Comparing February 22 to March 31, 1912, with the same period of 1914 and with the period January 19 to February 28, 1914, when the condition of the water approached that of the early spring of 1912.

DATES	BACTERIA PER CC.			PER CENT REMOVED	B. COLI COMMUNIS			TREATMENT
	Applied	Effluent filters	Treated water		Tests	1 cc. +	10 cc. +	
A								
1912								
February 22 to March 31.	17,000	760*	260	64	39	2	13	9 pounds bleach per 1,000,000 gallons water
B								
1914								
February 22 to March 31..	6,800	320	30	90	39	0	5	1.3 pounds liquid Cl per 1,000,000 gallons
C								
1914								
January 19 to February 28	12,000	710	118	83	41	0	5	4.5 pounds bleach January 19 to February 9 inc. 8 pounds liquid Cl. per 1,000,000 gals.

* Approximate. + = B. Coli present.

The water during the period of February 22 to March 31, 1912, was the worst water that the Torresdale plant has been called upon to handle.

Comparing A with B the efficiency of 1.3 pounds per million gallons compared with 9 pounds bleach, a ratio of 1–7, was 90 per cent against 64 per cent.

Comparing C with A this is a substitution of .8 pounds of liquid chlorine for 4.5 pounds of bleach or a ratio of 1–6, the number of bacteria in the effluent was 118 against 250 and the per cent of B. coli was correspondingly lower.

Test No. 2. In January, 1914, 870 pounds bleach and 105 pounds liquid chlorine was used per day. In March 234 pounds liquid chlorine was used; this is a substitution of 129 pounds chlorine for 870 pounds bleach, a ratio of 1–6.7. The following results were obtained.

	BACTERIA PER CC.			PER CENT REMOVED	B. COLI COMMUNIS		
	Applied	Effluent filters	Treated water		Tests	1 cc. +	10 cc. +
1913							
January	13,500	900	227	75	31	2	5
March . .	7,200	305	27	91	31	0	3

Test No. 3. Comparing November, 1913, with an average of 1620 pounds bleach per day and 90 pounds liquid chlorine during the last four days with March 1.3 pounds per million gallons or 234 pounds per day.

	BACTERIA PER CC.			PER CENT REMOVED	B. COLI COMMUNIS		
	Applied	Effluent filters	Treated water		Tests	1 cc. +	10 cc. +
November	8,500	170*	31	82	30	1	8
	7,200	305	27	91	31	0	3

* Approximate.

Test No. 4. Comparing April, 1913, with April, 1914.

	BACTERIA PER CC.			PER CENT REMOVED	B. COLI COMMUNIS			TREATMENT
	Applied	Effluent filters	Treated water		Tests	1 cc. +	10 cc. +	
1913								
April	3,320	50*	10	80	30	0	0	7 pounds bleach per 1,000,000 gallons water
1914								
April	2,070	89	11	88	30	0	1	1 pound liquid Cl

* Approximate.

Test No. 5. In February 800 pounds of bleach were used for eight days and during the month an average of one pound liquid chlorine per million gallons of water was used. The following results were obtained.

	BACTERIA PER CC.			PER CENT REMOVED	B. COLI
	Applied	Effluent filters	Treated water		
1914, February	7,250	460	99	78	4% positive in 10 cc.

In March with an effluent of 305 the treated water had a count of 27 per cc.

The complete data for the month of March, 1914, follow: 234 pounds liquid chlorine used per day or 1.3 pounds per million gallons water or .15 part chlorine.

TABLE IV

Daily tests at Torresdale for month of March, 1914

DATE MARCH 1914	BACTERIA PER CC.		EFFLUENT FILTERS			TREATED WATER, FILTERED WATER BASIN		
	River	Applied	Bact.	B. Coli		Bact. per cc.	B. Coli	
				1 cc.	10 cc.		1 cc.	10 cc.
1	13,000	3,400	200	0	+	5	0	0
2	1,600	850	140	0	+	12		
3	2,800	1,800	240	0	+	22		
4	4,000	1,800	240	0	+	14		
5	9,200	2,300	420	+	+	5		
6	9,200	3,200	140	+	+	25		
7	10,000	3,000	210	0	+	39		
8	2,700	1,900	50	0	0	9		
9	5,100	1,200	220	0	+	47		
10	10,000	220	160	0	+	4		
11	11,000							
12	10,000	3,900	200	0	+	9		
13	9,800	3,800	280	0	+	13		
14	12,000	3,600	260	0	+	30		
15	16,000	6,000	140	+	+	42		
16	24,000	4,500	270	0	+	59		
17	84,000	7,200	240	0	+	17	All 0 except 3d, 13th, and 20th on 10 cc.	
18	69,000	15,000	370	0	+	53		
19	91,000	7,400	500	0	+	35		
20	56,000	18,000	1,200	0	+	29		
21	44,000	32,000	920	+	+	230		
22	28,000	20,000	740	0	+	19		

TABLE IV—Continued

DATE MARCH 1914	BACTERIA PER CC.		EFFLUEMT FILTERS			TREATED WATER, FILTERED WATER BASIN		
	River	Applied	Bact.	B. Coli		Bact. per cc.	B. Coli	
				1 cc.	10 cc.		1 cc.	10 cc.
23	17,000	15,000	180	0	+	17		
24	12,000	6,200	240	0	+	14		
25	14,000	7,000	240	0	+	7		
26	12,000	6,600	140	0	+	10		
27	14,000	5,800	140	+	+	8		
28	14,000	5,500	100	0	0	10		
29	16,000	4,000	160	+	+	9		
30	40,000	5,200	170	0	+	14		
31	140,000	14,000	330	+	+	18		
		10,000	660	0	+	16		
Average.....	21,900	7,200	305			27		
Per cent of	time positive			23	94		0	10

EFFICIENCY OF LIQUID CHLORINE AT SCHUYLKILL RIVER PLANTS, CITY OF PHILADELPHIA

The following tables show the result of treatment with liquid chlorine and chloride of lime at Belmont, Queen Lane, Upper and Lower Roxboro Filter Plants.

Amount of Organic Matter in Solution

The amount of oxidizable organic material in solution in the filtered water from the Schuylkill River averages less than one-half that of the Delaware or approximately .75 part per million.

BELMONT FILTER PLANT[1]

The table (No. V) gives the results for the first three months of 1912, 1913 and 1914; also November and December, 1913.

The actual effect of treatment at this and the other three plants can only be estimated as the disinfecting apparati are so placed that no tests of filtered, untreated water can be obtained.

Bleach was first used at Belmont, March 19, 1912.

In September, 1912, the experimental liquid chlorine plant was started. The results for January, February and March, 1913, show the effect of this crude apparatus combined with bleach.

On November 18 the improved machine was started, 42 pounds of chlorine being substituted for 220 pounds of bleach or about 1–5.

The chlorine was later reduced to a range of 33–39 pounds or approximately 1–6.

No direct comparisons are available except during November, 1913.

1st–17th inclusive 220 pounds bleach were used. Average bacteria count was 8 per cc. B. coli out of 17 tests were present in 1 cc. twice and in 10 cc. were positive six times.

18–30 inclusive 42 pounds chlorine were used. Average bacteria count was 4 per cc. B. coli out of 13 tests but one positive test and that on 10 cc.

On February 27, the Liquid Chlorine Plant was down for two hours and the count went up to 260 per cc.

[1] Bacteria tests made by Dr. Geo. E. Thomas, Chemist in charge, Belmont Laboratory.

For the five and one-half months when chlorine was used out of 164 tests for B. coli only one positive test was obtained in 1 cc. and but 5 positive in 10 cc. or .6 per cent and 3.0 per cent.

In March, 1914, with an applied water of 10,700 bacteria per cc. the effluent averaged but five.

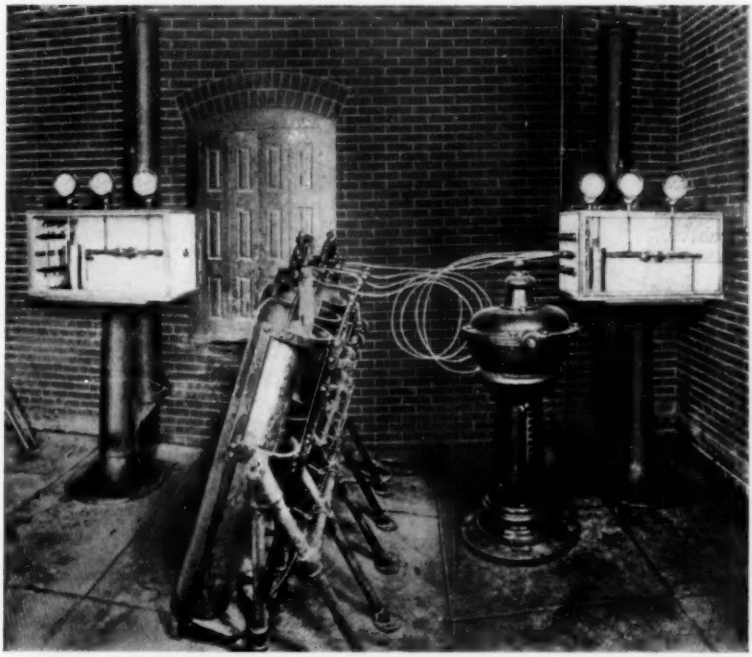
TABLE V

Showing the efficiency of Belmont Filter Plant

YEAR	BACTERIA PER CC.		B. COLI			TREATMENT
	Applied	Basin	Tests	1 cc. +	10 cc +	
1912						
January	1,940	622	14	6	9	None.
February	36,000	456	11	0	6	None.
March	38,400	354	31	2	16	Bleach March 19, 168 pounds, 4 per 1,000,000 gallons water
1913						
January	19,200	25	31	0	8	155 pounds bleach 40 pounds Cl day.
February	28,900	12	28	0	1	Bleach for 10 days at 35 pounds, chlorine 28 days at 39 pounds.
March	69,000	11	31	1	1	Bleach 18 days at 128 pounds, chlorine 18 days at 37 pounds.
November	4,270	6	30	2	7	220 pounds bleach to 17th, 42 pounds chlorine 18-30 inclusive.
December	20,200	25	31	1	2	Chlorine 34.5 pounds per day.
1914						
January	20,800	63	31	0	2	Chlorine 33 pounds per day.
February	14,000	7*	28	0	0	Chlorine 39 pounds per day.
March	10,700	5	31	0	0	Chlorine 37 pounds per day.

* Omitting February 27 plant out two hours count 260 per cubic centimeter.

	LBS. PER 1,000,000 GALS.	PARTS PER MILLION
1913		
December	0.88	0.11
1914		
January	0.83	0.10
February	0.98	0.12
March	0.93	0.11



No. 7. Liquid Chlorine Apparatus Belmont Filter Plant—Showing Cradles Since Abandoned

TABLE VI

Showing efficiency of Queen Lane Filter Plant

YEAR	BACTERIA PER CC.		B. COLI			TREATMENT
	Applied	Basin	Tests	1 cc. +	10 cc. +	
1913						
January.....	4,250	35	26	4	16	None
February.....	4,230	22	14	0	7	None
March.....	1,540	114	18	2	13	None
October.....	4,370	8	62	3	31	10 lbs. chlorine North Basin 90 lbs. bleach South Basin
November.....	2,250	6	60	0	6	34.5 lbs. chlorine per day
December.....	2,480	8	62	0	4	34.5 lbs. chlorine per day
1914						
January.....	3,140	26	62	2	4	36 lbs. per day chlorine
February.....	1,920	6	56	0	1	47 lbs. chlorine per day
March.....	1,520	5	58	0	1	37½ lbs. chlorine per day

	LBS. PER 1,000,000 GALS.	PARTS PER MILLION
1913		
November	0.70	0.09
December	0.70	0.09
1914		
January	0.72	0.09
February	1.00	0.12
March	0.75	0.09

TABLE VII

Showing efficiency of Lower and Upper Roxboro Filter Plants

Lower Roxboro Filters. Output approximately 10,000,000 gallons per day.

YEAR	BACTERIA PER CC.		B. COLI			TREATMENT
	Applied	Basin	Tests	1 cc. +	10 cc. +	
1911						
January	35,800	428	13	2	5	None.
February	14,000	515	10	2	2	None.
March	42,500	128	13	1	4	None.
1912						
January	27,700	580	14	5	7	First bleach January 26, 40 pounds per day.
February	40,600	47	11	0	0	47 pounds bleach per day.
March	33,500	83	27	0	0	60 pounds bleach per day.
1913						
January	12,800	12	31	0	3	32 pounds bleach per day.
February	21,500	8	28	0	0	32 pounds bleach per day.
March	43,800	40	31	0	1	32 pounds bleach per day.
November	3,940	2	30	0	1	Liquid Cl 6 pounds 2 days. Bleach 48 pounds 2 days both 2 days
December	12,600	9	29	0	0	Cl 6 pounds, 11d 3.5 pounds 20 days.
1914						
January	11,050	61*	31	0	2	Cl 5 pounds per day.
February	7,630	16	28	0	0	Cl 9 pounds per day.
March	10,650	5	29	0	0	Cl 9.5 pounds per day.

* Omitting 27–29 aver. = 21.

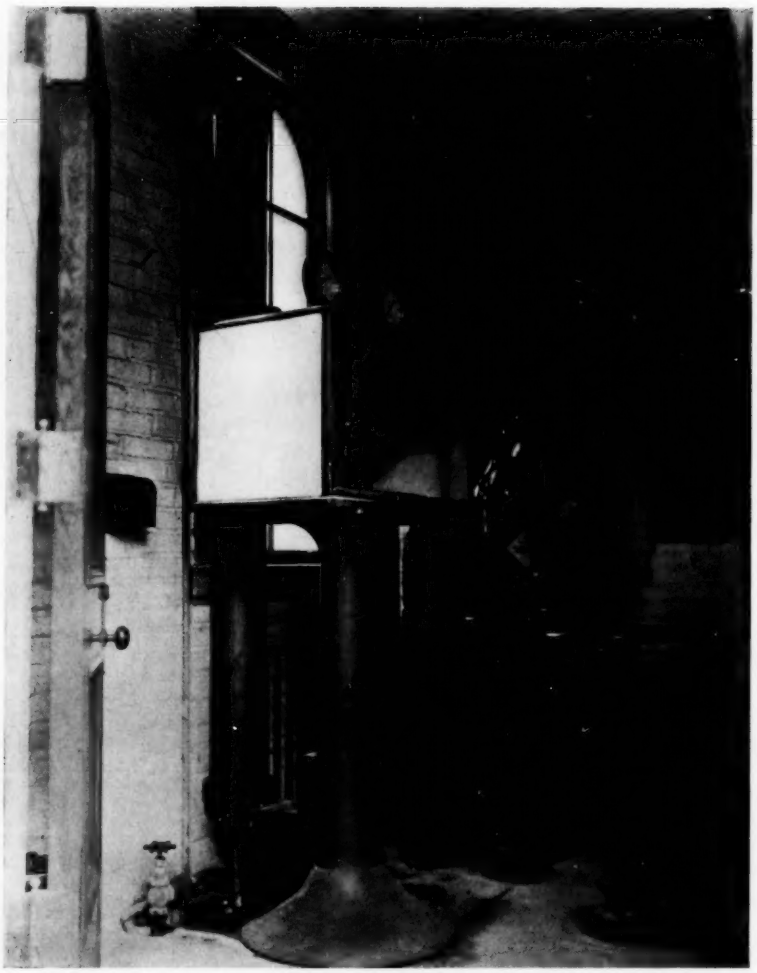
TABLE VII—Continued

Upper Roxboro Filters. Output approximately 15,000,000 gallons per day.

YEAR	BACTERIA PER CC.		B. COLI			TREATMENT
	Applied	Basin	Tests	1 cc. +	10 cc. +	
1911						
January	13,600	69	13	1	2	None.
February	13,500	24	10	0	0	None.
March	7,510	20	13	0	2	None.
1912						
January	7,150	92	14	1	6	First bleach January 27, 4 pounds per 1000.
February	12,200	19	11	0	1	80 pounds bleach per day.
March	20,000	38	27	0	3	94 pounds bleach per day.
1913						
January	2,450	6	31	0	0	45 pounds bleach per day.
February	3,240	8	28	0	0	45 pounds bleach per day.
March	2,700	8	31	0	2	45 pounds bleach per day.
November	960	1	30	0	0	1–8, 3 pounds Cl, 72 pounds bleach. 9–30, 9 pounds liquid Cl.
December	4,650	2	31	0	0	9 pounds liquid Cl.
1914						
January	2,460	4	31	0	1	9.5 pounds liquid Cl.
February	3,140	3	28	0	0	14 pounds liquid Cl.
March	2,600	2	30	0	0	14 pounds liquid Cl.

Liquid chlorine

	LOWER ROXBORO		UPPER ROXBORO	
	Lbs. per million gals.	Parts per million	Lbs. per million gals.	Parts per million
1913				
November	0.6	0.07	0.6	0.07
December	0.4	0.05	0.6	0.07
1914				
January	0.5	0.06	0.6	0.07
February	0.9	0.11	0.9	0.11
March	0.9	0.11	0.9	0.11



No. 8. Liquid Chlorine Apparatus Queen Lane Filter Plant

QUEEN LANE[2]

This plant was started January, 1913.

Table VI shows a comparison between untreated water and water treated with liquid chlorine. The need for treatment is shown by the results for March, 1913, with an applied of 1540 the effluent was 114. (This is from a green plant.)

In October 10 pounds chlorine were applied to the north basin and 90 pounds bleach to the south basin. Although the average bacteria count was but 8, B. coli was present in 10 cc.

B. Coli

North Basin	10 pounds chlorine	31 tests 1 cc.+2	10 cc.+15
South Basin	90 pounds bleach	31 tests 1 cc.+1	10 cc.+16

From November, 1913, to April, 1914, inclusive with about $\frac{3}{4}$ pound chlorine per million gallons, the average number of bacteria in the basin was 10 per cc., and B. coli out of 358 tests for 1 cc., 2 or .56 per cent were positive, and for 10 cc. 16 or 4.5 per cent.

LOWER ROXBORO[2]

Table VII shows the relation between untreated, treated with bleach and treated with liquid chlorine.

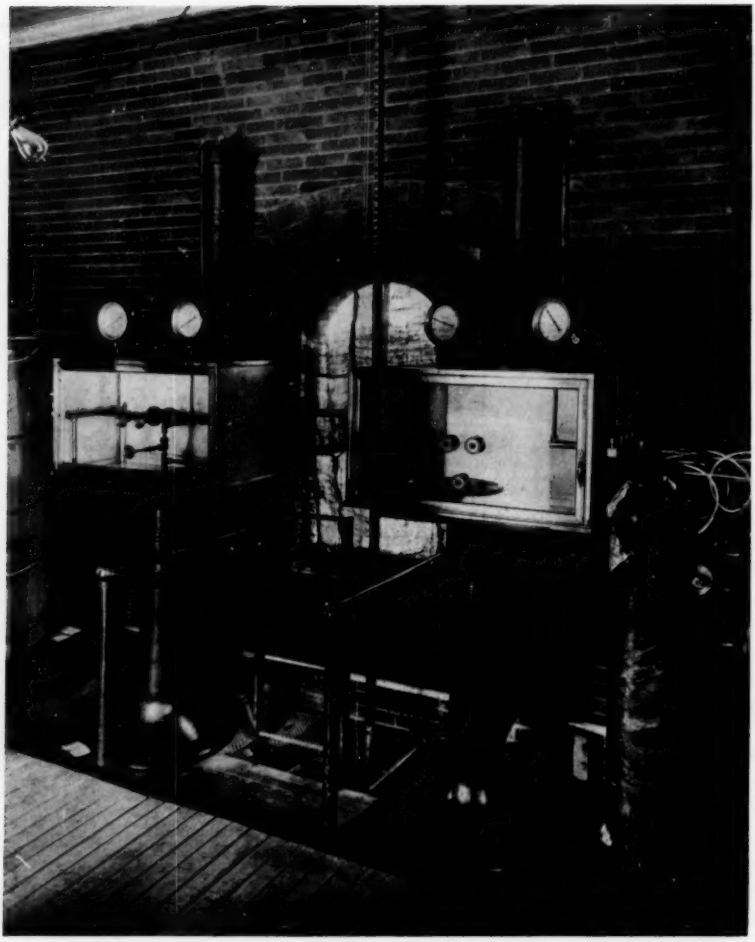
In November, 1913, a substitution of 6 pounds of liquid chlorine per day was made for 48 pounds of bleach. This 6 pounds was reduced to 3.5 pounds or .35 pound per million gallons on December 12, the count for December averaging but 9 with B. coli absent. Excellent results were obtained with but 3.2 pounds of bleach per million gallons of water.

Since the introduction of liquid chlorine, to April 30, at Lower Roxboro, out of 168 tests for B. coli not ONE positive test in 1 cc. was obtained, and only three in 10 or 1.8 per cent.

UPPER ROXBORO[2]

This is the banner plant of the city. Its high efficiency in the past without treatment has largely been due to the fact that eight days sedimentation precedes filtration. The table shows the results from untreated, treated with bleach, and treated with liquid chlorine. The counts are so uniformly low both with the use of bleach and with liquid chlorine that it is hardly possible to compare counts of 2

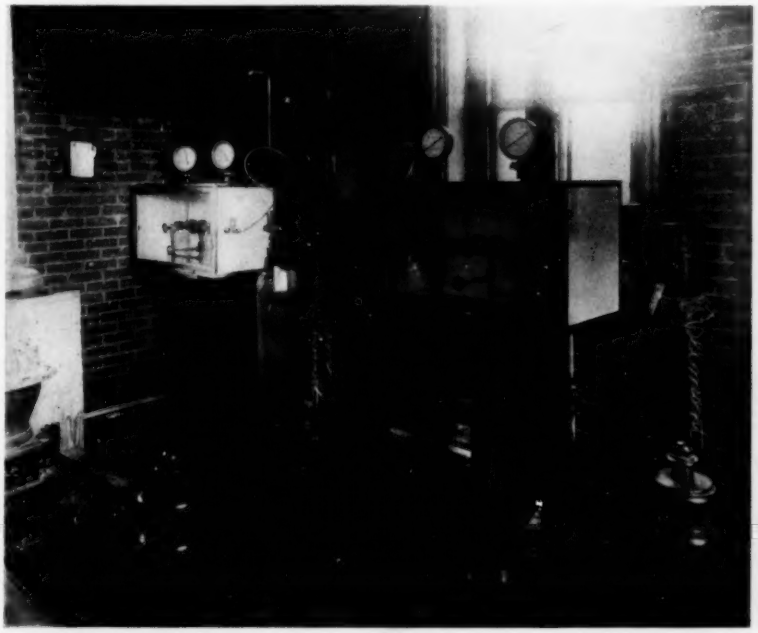
[2] Bacteria tests made by Dr. Geo. E. Thomas, Chemist in charge, Belmont Laboratory.



No. 9. Liquid Chlorine Apparatus Upper Roxboro Filter Plant

with 8 or 1 with 6. It is sufficient to note that since the introduction of liquid chlorine in November, 1913, an average count of but three has been obtained and that there has been but one positive test for B. coli out of 172 tests and that in 10 cc.

The amount of 14 pounds chlorine per day seems excessive, in fact on April 14 the amount of chlorine used at all the Schuylkill plants with the exception of Queen Lane was reduced to $\frac{1}{2}$ per million gallons or a cost of but 5 cents per million.



No. 10. Liquid Chlorine Apparatus Lower Roxboro Filter Plant

Summary of Schuylkill plants, November 1913–March 1914 inclusive

PLANT	B. COLI COMMUNIS				
	Tests	1 cc.	Per cent	10 cc.	Per cent
Queen Lane	358	2	0.56	16	4.5
Belmont	164	1	0.61	5	3.0
Lower Roxboro	168	0	0	3	1.8
Upper	172	0	0	1	0.58
Totals	862	3	0.35	25	2.9

WILMINGTON, NORTH CAROLINA

The writer is indebted to Mr. Geo. F. Catlett, Chemist, Consolidated Boards of Health, Wilmington, North Carolina, for a very complete account of the water conditions at Wilmington, including experiences with bleach and liquid chlorine, a part of which is presented here.

Source of supply, Cape Fear River, capacity 4,000,000 gallons daily. Output about 2,000,000 gallons.

Analysis of water

	RIVER	FILTERED
Color	100–200	0–20
Alkalinity	5–7	9–14
Turbidity	10–50	0–5
Oxygen consumed	16.9	3.9 (30 min. Boil?)
Bacteria per cubic centimeter	2000–3000	50–200
B. coli	Present 1 cc.	Present 10 cc.

Type of Plant: Mechanical, 8 filters, 500,000 gallons capacity.

Treatment 3 to 3.5 grains per gallon alum together with the necessary soda ash used to coagulate the water and remove color.

Filtered water treated with bleach and later liquid chlorine.

Bleach added to filtered pump well corroded plungers and packings. Later a small force pump was used on the discharge side of the pumps. This became clogged with lime sludge. Quantity of bleach 3 parts per million available chlorine.

By May, 1913, the sand on the filters was allowed to get so low that the filters showed B. coli in 1 cc. The Board of Health insisted on the restoring of sand and the application of a proper bleach apparatus. The use of a liquid chlorine machine was recommended and a machine installed.

Table VIII gives the averages for ten months of raw, filtered and treated (with bleach). Three-tenths part of available chlorine, about 8 pounds powder per million was used. It will be seen that the treated water had a comparatively high count and that the bleach removed about 67 per cent of the bacteria. The substitution of .18 part of liquid chlorine while it removed 80 per cent of the bacteria did not remove all B. coli and 158 bacteria per cc. remained. During this period the filters were being resanded.

TABLE VIII

RESULTS OF TREATMENT AT WILMINGTON, NORTH CAROLINA

Monthly averages (showing gradual deterioration of filter efficiency)

BACTERIA PER CC.			B. COLI COMMUNIS PER CENT POSITIVE						COLOR TURBIDITY			
			Raw		Filtered		Treated					
Raw	Filtered	Treated	10 cc.	1 cc.	1 cc.	10 cc.	1 cc.	10 cc.	Raw	Filtered	Raw	Filtered
1,860	63	21	0	50	0	0	0	0	114	9	27	0.25
2,190	57	36	100	100	0	0	0	0	115	10	32	1.5
2,775	86	24	80	100	0	0	0	0	137	8	25	0.75
1,800	78	19	20	87	0	12	0	0	122	7	35	1.0
2,700	196	61	0	100	8	25	0	3	126	9	21	slight
2,900	258	87	0	33	26	40	0	12	150	12	22	0.75
1,750	286	126	0	50	30	100	0	18	136	14	39	3.5
2,525	348	113	0	100	40	100	0	0	175	16	21	0.5
2,240	640	99	0	75	56	100	26	60	116	18	43	9.0
1,280	782	158	0	60	60	100	21	37	146	16	31	slight
Av. 2,230	279	74							134	12	30	
Per cent removed.	87.5	73.5*										

0.1 cc. tests of filtered and treated water all negative.

* 10 cc. tests all positive.

3 ppm. Hypo used except last month when 0.18 ppm. liq. chlorine used.

Table IX gives the daily results November 17 to December 22, 1913, with the use of .3 part liquid chlorine.

Mr. Catlett, writing April 6, states: "After the filters were repaired we went back to .18 parts chlorine (1.5 pounds per million gallons) and our water as it goes to the consumer is almost sterile,

TABLE IX

Wilmington, North Carolina. Daily averages after application of 0.3 p.p.m. liquid chlorine (raw water averaging about the same as in table I)

DATE	BACTERIA PER CC.		B. COLI COMMUNIS				COLOR, FILTERED	TURBIDITY
	Filtered	Treated	Filtered		Treated			
			1 cc.	10 cc.	1 cc.	10 cc.		
November								
17	125	16	+	+			5	
18	320	6	0	+			5	
19	215	3	+	+			10	
20	180	5	0	+			10	
21	135	8	0	+			5	
22	98	6	0	+			5–10	
24	105	2	0	+	All ne	gative	0–10	
25	200	12	+	+			5	
26	135	2	0	+			10	
28	255	6	+	+			10	
29	340	4	+	+			5	all 0
December								
3	135	3	0	+			10–15	
4	160	4	0	+			15	
5	140	5	+	+			5–10	
6	210	4	0	+			10	
8	95	3	0	+			5–15	
9	325	6	+	+			5	
10	80	5	0	+			5–10	
11	75	15	0	0			5–10	
12	95	11	0	0			10	
13	120	23	0	+			25	
15	185	16	0	+			10–30	
16	140	10	0	+			10–20	
17	65	12	0	0			5–15	
19	50	4	0	+			5	
20	65	2	0	0			5–10	
22	75	2	0	0			5–10	
Average.....	153	8						
Per cent removed..		94.8	Note filters were being repaired during this period					

and continues so from day to day without interruption. The chlorination apparatus gives no trouble; with the exception of some minor leaks, it is only necessary to couple up a new tank of chlorine when empty. We can now use the man's time formerly spent in mixing and preparing the bleach for other purposes. The new installation requires about one-tenth the attention." The reason attributed by Mr. Catlett for the need of more chlorine than we find necessary is the fact "That the raw water contains an abnormal amount of organic matter, brought down from the swamps in the water shed and a good part of the oxygen is used by this."

WILMINGTON, DELAWARE. RESULTS OF HYPO AND CHLORINE TREATMENT

The following figures are taken from the annual report of Mr. Edgar M. Hoopes, Chief Engineer, Water Department, Wilmington, Delaware.

Year 1912 February to April 27, inclusive.

Quantity of bleach, 7 to 22½ pounds per million gallons, average 11½ pounds.

Bacteria per cc.

Applied	39,600	
Effluent filters	2,400	This is a removal of 94 per cent
Treated	150	

Year 1913 March to June inclusive.

Liquid chlorine average 1.56 pounds per million gallons, ratio 1 to 7.

Bacteria per cc.

Applied	9,100	
Effluent filters	102	A removal of 85 per cent
Treated water	15	

In March *Journal of the American Water Works Association* Mr. Hoopes writes that during eight months in 1913 when he used an average of 1.56 pounds chlorine the bacteria count was:

Before treatment	302	
After treatment	51	83 per cent removed
B. coli	11.97	
After treatment	2.77	77 per cent removed

The condition of the water treated with chloride of lime and that treated with liquid chlorine are not exactly comparable, one having about 2400 bacteria per cc. and the other an average of 302.

USE OF LIQUID CHLORINE WITH UNFILTERED WATERS MONTREAL, CANADA

Mr. John H. Harrington, chemist in charge, supplies the following information.

"Liquid chlorine has been used at the Low Level Pumping Station since December, 1913, and has given satisfactory results on raw waters of widely varying alkalinity and organic content. The water at the intake is made up of varying proportions of water from the St. Lawrence and Ottawa rivers the general characteristics of which are as follows:

Results of liquid chlorine treatment at Montreal, Canada. Parts per Million

	ALKALINITY	OXYGEN ABSORBED (30 MIN.)	DOSE REQUIRED CHLORINE	BACTERIA PER CC.	PER CENT REMOVED
Ottawa	20	14.0	1.50	3000	over 98
St. Lawrence	90	3.5	0.30	300	over 99

"For mixtures of the two the dose is larger as the proportion of Ottawa water is larger." This is a dose of from 2.5 to 12.5 pounds of chlorine per million gallons. Mr. Harrington makes no mention of taste. It is presumed the water does not have a taste.

NIAGARA FALLS, NEW YORK. PLANT OF WESTERN NEW YORK WATER COMPANY

Liquid chlorine was used throughout the year 1913, 1½ pounds per million gallons of water being used with 1.17 grains per gallon alum, with the raw water and ½ pound liquid chlorine per million gallons used with filtered water.

In 1912 July to December, inclusive, an average of 1.85 grains per gallon of alum were used with 3.92 pounds hypo per million gallons water (hypo applied to filtered water). In 1913 1.17 grains alum were used, or a saving of nearly .7 grain per gallon or at 1 cent per pound about 90 cents per million gallons water by using 1 pound liquid chlorine per million gallons.

In 1912 thirty pounds of chloride of lime were used for 6,000,000 gallons of water, applied to the effluents of the filters.

Water is pumped to settling basin, treated with alum and liquid chlorine, flows by gravity to filters and clear well, final effluent treated with liquid chlorine. By the use of 1½ pounds chlorine Mr. Huy, the engineer in charge, states that he was able to make a material saving in the amount of alum needed.

The following table (X) summarizes the results with liquid chlorine for the year 1913.

1914, January to March, inclusive.

Raw water averaged 23,600 bacteria per cc.

Treated water averaged 17 bacteria per cc. with but 1 positive test for B. coli out of 227—1-cc. tests.

In 1912 during the same time the treated water averaged 44 bacteria and B. coli was present in 1 cc. 4.8 per cent of the time.

The above table shows the increased efficiency of liquid chlorine when used with filtered waters compared with its use with unfiltered water (see also results from Montreal).

ADVANTAGES OF LIQUID CHLORINE OVER CHLORIDE OF LIME

There are several claims made for liquid chlorine, an analysis of which may prove of value.

1. That liquid chlorine is an absolutely pure chemical, concentrated in small cylinders while chloride of lime is bulky, requiring large space for storing.

As far as we have been able to determine the liquid chlorine we have handled is pure, the chief impurity being ferric chloride, due to the action of the chlorine on the cylinder.

2. As to the saving in space required a 100 pound cylinder occupies 64 square inches floor space. A stock for 50 days at 200 pounds a day would occupy a space of 45 square feet 5 feet high.

Twenty thousand pounds of bleach enough for but 17 days at 1200 per day would occupy (taking the cans at 750 pounds each) 160 square feet. On a basis of 6 to 1 about 10 to 11 times as much space is required for bleach as for liquid chlorine.

3. With efficient controlling devices liquid chlorine will eliminate the disagreeable odors and corrosive influences of chloride of lime; consequently the installation may be placed in positions where the use of chloride of lime is impossible.

TABLE X

Plant W. N. Y. W. Co., Niagara Falls, Monthly averages

1913 MONTH	BACTERIA PER CC.			B. COLI PER CENT +			TURBIDITY		GRS. ALUM PER GAL.	LBS. Cl M.
	Raw	Settled	Filtered	Treated	Filtered	Treated	Raw	Filtered		
January	18,300	3,450	334	40	49	4	404	0	1.98	1.59
February	19,700	4,890	363	42	51	2	139	0	1.23	1.65
March	30,800	4,580	352	51	46	6	394	3	1.94	1.79
April	24,900	3,310	253	21	18	0	158	0	1.29	2.14
May	33,800	7,320	422	22	30	0	80	0	1.20	2.17
June	39,000	10,100	894	27	64	0	42	0	0.91	1.86
July	43,500	7,570	564	24	68	2	48	0	0.88	1.99
August	32,000	4,370	414	22	71	0	20	0	0.81	2.11
September	33,000	3,640	322	17	47	0	16	0	0.80	2.23
October	30,700	4,010	334	13	28	0	39	0	0.88	2.07
November	27,500	3,910	280	14	24	0	86	0	1.12	2.39
December	19,700	3,070	352	11	36	1	95	0	1.05	2.12
Average	29,400	5,020	407	25	43	1.3	126.6	0	1.17	2.01
Per cent removed		82.9	91.9	93.9						
Per cent removed plant				99.92						
Per cent removed B. coli					56.6	97.2				

Ordinarily this is true. The odor of chlorine at Torresdale is hardly noticeable; but there are times when, due to carelessness or accidents, the atmosphere has been unbearable and chlorine has escaped in large amounts. (This has usually been caused by the failure of the water supply used for absorption and not by the apparatus.)

4. Liquid chlorine will retain its full efficiency over unlimited time whereas chloride of lime deteriorates rapidly. This is one of the best arguments for liquid chlorine, especially for small installations.

5. The floor space occupied by liquid chlorine plants is small, whereas chloride of lime installations require large mixing tanks, etc.

The space occupied at Torresdale for bleach treatment independent of the space for weighing was 22 feet by 16 feet; for the liquid chlorine apparatus; the cabinet is 2 feet by 4.4 feet and the space occupied by the towers is 10 feet by about 2 feet.

6. The reaction with liquid chlorine is simplified, while that with chloride of lime is complex and less effective at low temperature.

The reactions for chloride of lime probably are

$$Ca\begin{matrix}Cl_2\\OCl\end{matrix} + CO_2 + H_2O + = CaCO_3 + 2\ ClOH + CaCl_2$$

$$2\ ClOH = 2\ HCl + O$$

$$2\ HCl + CaCO_3 = CaCl_2 + H_2O + CO_2$$

Jackson (Sterilization of Cleveland Water Supply) gives the first part of the reaction as $CaOCl_2 + H_2O + CO_2 = CaCO_3 + HOCl + HCl$.

LIQUID CHLORINE

Jackson gives $Cl_2 + H_2O = HOCl + HCl$ and $HOCl + HCl = HCl + O$.

It is a question if hypochlorous acid is formed and the author prefers the simple reaction of $Cl_2 + H_2O = 2\ HCl + O$.

This is a liberation of 23 per cent by weight of nacent oxygen and which together with the powerful disinfecting action of the chlorine itself acting before it decomposes water gives the increased efficiency.

It has been noticed in some places (Belmont Filter Plant in 1912) where the dry gas has been fed directly into the water to be treated, that bubbles rise to the surface, especially when large amounts are used. This is due to the fact that the specific gravity of the gas is so low that it rises to the surface before it has time to be

absorbed by the water. At 234 pounds a day we use 2.6 ounces per minute or at O°C 760 mm. pressure about 1420 cubic inches per minute or nearly one cubic foot.

7. According to Mr. D. D. Jackson (Proceedings American Water Works Association, 1913) 1 pound liquid chlorine equals 9 pounds chloride of lime; according to Mr. J. A. Kienle (Proceedings American Water Works Association, 1913) it equals eight. Theoretically it should equal about three, but in practice considerable available chlorine is lost and the theoretical amount is nearer 1 to 4.

Mr. Huy at Niagara Falls claims to get as good results with 3 pounds of liquid chlorine per day with 6,000,000 gallons of water as he did with 30 pounds of powder. He added 30 pounds to the filter effluent. He added 9 pounds liquid to the water in the sedimentation basin and 3 pounds to the effluent of the filters. The results are not quite comparable.

At Torresdale we are using liquid chlorine at the rate of about 1 to 6 to 1 to 7. It is quite possible that with careless handling and storing of bleach at small plants the figure is nearer 1 to 8 than 1 to 6.

8. No taste or odor appears in water treated with liquid chlorine.

Major Darnell states that at least two parts of liquid chlorine equivalent to 16 pounds per million gallons must be used to give the slightest taste to Potomac River water. Mr. Huy stated that when using 5 pounds per million gallons a slight taste was noticed in the laboratory directly after dosing. On a test at the Connecticut Hospital for the Insane, Middletown, Connecticut, 14 pounds per million gallons were used without its being noticed.

It is quite possible that if the dosage is heavy enough the water will have a taste. Figuring on a basis of 6–1, 30 pounds of chloride of lime would be needed to correspond to Mr. Huy's 5 pounds; and 80 pounds to the amount mentioned by Mr. Darnell.

From a close examination of the literature on chloride of lime and from personal observation, the amount of chloride of lime that will give a taste to water may be estimated at from 7 to 20 pounds per million gallons water, the average figure will be from 10 to 12. At the above rating this would mean 2 pounds liquid chlorine. A heavy overdose can be given without complaints.

9. Liquid chlorine does not change the character of the water by the introduction of lime salts. The lime salts will usually amount to not over one part per million.

10. Liquid chlorine necessitates no labor cost while chloride of lime does. This is true, but a liquid chlorine requires skilled supervision to be operated properly and is not fool proof.

11. Liquid chlorine leaves no sludge. This is self-evident.

12. Liquid chlorine will reduce the amount of alum needed for bacterial removal. There can be no question but that, in cases where the water is comparatively clear and where alum is used chiefly for bacteria removal, if liquid chlorine is used before filtration it will make a marked saving in the cost of alum and in many cases will not only pay for itself but will decrease the general cost of the plant.

A saving of one-half grain per gallon of alum at 1 cent per pound by the use of 1 pound liquid chlorine per million gallons at 10 cents means a saving of 61 cents per million gallons.

13. The feed of liquid chlorine is regular from hour to hour and the feed of chloride of lime varies constantly.

The irregularity of the feed of bleach at Torresdale under the best of conditions was shown in the first part of this paper.

We make readings of the gauges on the liquid chlorine machines every hour and a half and the fluctuations during any one day will not ordinarily vary over one-half pound from the desired amount.

That the disinfection is continuous throughout the twenty-four hours is shown by the following table (XI) giving maximum, minimum and average results of tests every two hours for fifteen days.

Samples marked House No. 2 Lardner's Point were collected from Pump No. 10, Lardner's Point Pumping Station, three miles from Torresdale Basin. The averages are averages of 12 tests made every two hours. The samples from the effluent of the filters and the filtered water basin are collected at 9 a.m.

OBJECTIONS OF USE OF LIQUID CHLORINE

The chief objection to the use of liquid chlorine lies in the concentrated energy of the material itself. If liquid chlorine is set free in small enclosures it will cause nausea. With ordinary common sense and judgment on the part of the operator this is not likely to happen. The greatest danger lies in faulty cylinders and faulty valves. If the cylinder valve will not turn off, or if the cylinder leaks, it must be gotten out to the open air and the chlorine allowed

to escape. Careful inspections of cylinders and valves must be made. Liquid chlorine when it comes in contact with moisture has a very corrosive action, but this has been overcome by the use of hard rubber pipes and towers.

The above summarizes the advantages of liquid chlorine; the objections are comparatively few in number.

TABLE XI

Showing regularity of disinfection. Bacteria per cubic centimeter

DATE	EFFLUENT FILTERS	FILTERED WATER BASIN	LARDNER'S POINT HOUSE NO. 2			
			Maximum	Minimum	Average	Liq.Cl. lbs. per M. gals.
March						
28	160	9	28	7	13	1.3
29	70	14	20	6	13	1.3
30	330	18	25	8	15	1.3
31	660	16	23	10	17	1.3
April						
1	520	11	28	8	16	1.3
2	680	51	41	4	16	1.3
3	200	15	24	6	15	1.3
4	170	10	27	8	14	1.3
5	120	16	51	7	17	1.3
6	71	8	29	3	12	1.3
7	62	8	16	5	9	1.2
8	47	8	15	6	9	1.0
9	57	9	15	6	10	1.0
10	45	18	14	9	12	1.0
11	94	18	17	9	13	1.0

COMPARATIVE COSTS

The following estimated comparative figures are submitted:

Chloride of lime costs us from $1.22 to $1.70 per 100 pounds, the usual quotation was $1.34 and the average figure $1.40.

Taking $1.40 as a basis; we used during 1913 an average of a little over 1200 pounds a day or $16.80 a day for powder.

Two laborers at 25 cents per hour were employed for eight hours or $4 per day, making a total cost of $20.80 per day exclusive of repairs, sample collecting of laboratory analyses.

One hundred and eighty pounds of liquid chlorine (the amount used April 10) would cost at 10 cents per pound $18 per day.

We have now passed the worst conditions of the year, February and March, when we used 234 pounds a day or $23.40 cost.

It is expected that we will be able to reduce the amount of liquid chlorine to at least three-fourths pound per million or 120 pounds a day. We reached this April 22.

Some supervision and handling of cylinders is required. At present the work is done by a $3 a day mechanic who also keeps the pre-filters in repair. His wages are charged against the pre-filters. A charge of $1 per day would be fair for this service. This is partly balanced by the discontinuance of laboratory analyses.

The labor cost during 1913 of $4 per day at Torresdale with its output of 180,000,000 gallons amounted to but 2.2 cents per million gallons. At Belmont and at Queen Lane the labor cost of about $1.50 per day amounted to 3.8 cents and 3 cents respectively.

At the Roxboro plants the labor cost averaged over $1 per day for mixing; this at Lower Roxboro cost 10 cents per million and at Upper Roxboro 6.7 cents per million.

The cost per million gallons at these plants during 1913 amounted to 16 to 18 cents. At 1 pound per million gallons for liquid chlorine the cost would be 10 cents, or a saving of 6 to 8 cents per million gallons. On April 14 the quantity used was reduced to one-half pound per million or a cost of 5 cents, a saving of 11 to 13 cents per million.

Belmont and Queen Lane are saving a labor cost of 3.8 and 3 cents per million gallons. Belmont is operating at a rate of one-half pound and Queen Lane at one-half pound or about 5 cents each.

On April 21 the amount used at Torresdale was reduced to three-fourths pound or a cost of $13.50 per day exclusive of a possible charge of $1 for labor.

In general the cost of the two processes should be about equal; if anything, liquid chlorine should prove the cheaper.

GENERAL SUMMARY AND CONCLUSIONS

Disinfection has been found absolutely necessary at Torresdale; at least one-half part of chloride of lime, or the minimum we reached in 1913 of 800 pounds a day, is needed.

With the use of liquid chlorine it is necessary to have an accurate determination of the flow of gas; it must be kept in a condition that it will not corrode the apparatus and a proper absorption of

the gas must be obtained. This has been accomplished by the use of absorption towers, which require from 50 to 100 gallons of water per 1 pound of chlorine used.

While in some instances liquid chlorine may prove more costly than chloride of lime; the regularity with which it can be applied, the more effective action on pathogenic bacteria, the small compact apparatus and the absence of the odor of chlorine around the plant, recommend it as a satisfactory substitute for hypochlorite, having as it does all the advantages of the latter and only some of the faults.

DISCUSSION

MR. WILSON F. MONFORT: The speaker has been very much interested in Mr. West's paper, and regrets that at St. Louis we were unable to contribute anything, because the water we were treating with liquid chlorine so rarely showed any indications of the B. coli. We had negative results before treatment regularly, almost universally, and the disinfecting action was almost nil.

There is one question that has been brought up with regard to the relative efficiency of hypochlorite of lime and liquid chlorine that should be pushed a little further. It is not the matter of cost, it is the matter perhaps of uniformity of application as affecting after-growths that have been commonly noted for a number of years where hypochlorite of lime is used. The speaker desires to raise that question and hopes that Mr. West may be able to give us an answer, as to whether he has discovered any after-growths in the use of hypochlorite or when using liquid chlorine? It has occurred to the speaker that the liquid chlorine diffusing so very rapidly there is a possibility of much more efficient sterilization of the water; whereas the hypochlorite solution, as often made, is diluted and may be diffused much less rapidly, and the efficiency of application be considerably lower. If it be true that hypochlorite diffuses more slowly than chlorine, and the speaker thinks that is true, then we should expect some organisms to get by. In our testing, out of every 100,000 gallons we are collecting a sample probably of 100 cc. and we need a larger number of samples perhaps in order that a fair test may be made. With the liquid chlorine, so far as our observations go, there are no after-growths to be found. It seems that the bacilli that remain afterward are of such a class that they do not rapidly increase in the distribution systems, and that that

may be due in large part not only to the efficiency of the liquid chlorine itself, but to the superiority of its diffusion and the improved quality of the mix that one gets by using the chlorine solution as against the hypochlorite solution with its extreme variation in strength, even when the same material is used, as Mr. West has shown.

MR. FRANCIS D. WEST: In reply to that question the author would state that he had intended, at a later date, to take up the subject of the apparent difference between bleach and liquid chlorine as to the lasting effect on bacteria in water or, in other words, in relation to after-growths.

When using bleach we found an increase in the number of bacteria in the water in our mains; studies were made along certain pipe-lines. These studies showed that there was a gradual increase with increasing distance from the filter plant.

As there were other influences affecting the count, such as the existence of dual connections, it is quite possible that many of the increases were not caused by bacterial development.

Previous to the installation of the liquid chlorine plants, all these influences, with the exception of storage in open reservoirs, were removed. The following tables give the data for district samples for the months of April and May, 1914:

Torresdale filtered water basin

MONTH	BACTERIA PER CC.			B. COLI CUMMUNIS		
	Average	Maximum	Minimum	Tests	1 cc. +	10 cc. +
April	13	52	4	31	0	1
May	9*	34	3	31	0	3

* Omitting May 28–29 Filter Plant, shut down due to break at Lardner's Point Pumping Station.

DISTRICT SAMPLES

Averaging 19 sampling points and omitting two sources supplied through open reservoirs.

MONTH 1914	AVERAGE BACTERIA PER CC.			B. COLI COMMUNIS		
	Maximum	Minimum	General	Tests	1 cc. +	10 cc. +
April	45	9	15	222	1	3
May	32	6	13	218	2	8

The following table shows the results from eight sampling points, each a mile apart.

LOCATION	DISTANCE FROM TORRESDALE BASIN	BACTERIA PER CUBIC CENTIMETER					
		April			May		
		Max.	Min.	Average	Max.	Min.	Average
	miles						
5900 Torresdale Avenue	4	37	3	12	11	3	6
*Main and Foulkrod Streets	5	430	10	140	1800§	50	100
Erie Avenue East Frankford	6	63	5	15	13	4	9
Front and Kensington	7	32	4	11	15	4	9
Beach and Poplar Streets	8	16	4	10	18	2	8
712 North 5th	9	27	3	9*	27	6	9
516 South Street	10	44	11	21	24	3	8
Pennsylvania Salt Works	11	24	8	12	17	5	12

* 5 miles direct 8¼ miles by way of Wentz Farm (open reservoir).
§ Reservoir treated with copper sulphate.

B. coli 178 tests 1 cc. + = 1 10 cc. + = 4.

It will be seen that with the exception of the water coming from Wentz farm reservoir, which shows the development on storage due to algae growth, there is practically no difference between the sampling points. General averages of 15 and 13 compared with 13 and 9 show that no after-growths occur in the filtered water disinfected with liquid chlorine.

The action seems to be decidedly superior. My conclusion is that the action is more permanent with liquid chlorine than with chloride of lime.

MR. ROBERT SPURR WESTON: Mr. West very kindly placed this paper in the speaker's hands, and it has been read through with a great deal of interest. As he has described in detail the efficiency of the economical process which he is using at Torresdale, there is little which the speaker can add, except to approve of his use of liquid chlorine, even for so large an installation.

The experience at Exeter, New Hampshire, where experiments with both bleaching powder and liquid chlorine have been used, may be of interest, although they have not been completed. At this plant it was impossible to coagulate the water to a satisfactory degree by the use of sulphate of alumina alone. This was because

of the low alkalinity of the reservoir water, and the fact that it is taken from an impounding reservoir, which about four years ago was enlarged by raising the dam, causing the flooding of a large area which is overgrown with vegetation. This vegetation impregnates the water with a kind of colloidal vegetable matter, resembling in its physical and chemical properties cucumber or quince seed juice more than anything else. When treated with the amounts of sulphate of alumina which could be used without increasing the alkalinity artificially (about 2 grains per gallon) and subjecting the water to a 4-hour period of coagulation, the color was reduced on an average from 80 to 20 parts per million, and it could not be reduced below 10 parts, even with the use of excessive amounts of sulphate of alumina and the necessary soda. Furthermore, the gelatinous vegetable matter collected in the sand not only made frequent washings of the filters necessary, but collecting at the surface made it imperative to remove the accumulation by scraping. This accumulation persisted in spite of the fact that the arrangements for washing the filters were improved.

Beginning last year bleach was added to the water in the proportion of 0.4 parts of available chlorine per million, and recently liquid chlorine has been used in its place. It was found that more work could be accomplished by using 0.4 parts of chlorine per million than by the use of 15 parts of sulphate of alumina.

At present 0.58 part of liquid chlorine per million is being added, and practically perfect results are being obtained, notwithstanding the fact that the water from the Exeter reservoir is one of the most difficult to treat which the speaker has encountered, for, besides the color and vegetable matter, the water at times contains considerable clay, washed from the banks of the reservoir by the waves during storms.

Comparing a sample collected for analysis in June, 1913, with one collected in June, 1914, the results shown in the following table were obtained.

The Association owes a great debt of gratitude to Mr. West for this admirable presentation of his work and for the very good résumé of the whole subject, concerning which information is not very generally diffused. The value of the paper will become more apparent as it is read, than during the limited time that Mr. West has had for its presentation.

Results of purification with and without the use of chlorine

	PARTS PER MILLION	
	June, 1913	June, 1914
Color, reservoir	90.0	75.0
Color, effluent	45.0	6.0
Turbidity, reservoir	15.0	18.0
Turbidity, effluent	4.0	1.0
Oxygen consumed, reservoir	9.40	7.52
Oxygen consumed, effluent	5.45	2.92
Alkalinity, reservoir	21.0	18.0
Alkalinity, effluent	13.0	9.0
Albuminoid ammonia, reservoir	0.308	0.304
Albuminoid ammonia, effluent	0.178	0.142
Iron, reservoir	0.65	0.45
Iron, effluent	0.40	0.08
Increase in chlorine	0.0	0.36
Chlorine added	0.0	0.50
Bacteria at 20°C., reservoir	350.0	148.0
Bacteria at 20°C., effluent	45.0	14.0
B. coli, reservoir	Positive	Negative
B. coli, effluent	Negative	Negative

MR. J. WALTER ACKERMAN: Mr. West wrote to the speaker in relation to what we were doing at Auburn. Unfortunately the speaker was not able to give him any particular results, for the reason that at the time we were applying the hypochlorite and we did not have the advantage of a bacteriologist on the job. We now have a bacteriologist employed constantly. In October of last year we began the application of liquid chlorine. Of course the speaker was very glad to know that Mr. West had had some of the difficulties of the application of hypochlorite that had been our experience; notably, our pump packings went to pieces, and of course stopped up the orifices of the tanks, and we were under some uncertainty as to whether the piping was not stopped up also. That is an experience common to all of us in that line. We are on perhaps the border line of the places that can afford to have all this apparatus and the smaller places, our daily use being a little over 6,000,000 gallons per day.

As to the matter of cost which has been mentioned so many times, is not the cost a comparatively small matter, that is the relative cost between one and the other, if you can get any better results from

one than the other? The cost per million gallons is so small that it is practically negligible; and when you take into consideration the benefits that you get, the cost is so little that it should hardly be given consideration. The water which we have is an unfiltered raw water; and although it is from a lake of 10 square miles in area and our sedimentation under normal conditions is fair, our raw water running, excepting during the spring floods, under 100 bacteria per cubic centimeter, in the spring floods we sometimes get as high as 5000.

As to the after-growths, the speaker cannot say anything about them with hypochlorite, but does note a slight difference at the present time when we take our samples. If we take a sample immediately in the pump discharge we are apt to get a slightly higher count than in the city.

The author has well spoken of the labor connected with it. There is one thing he omitted to speak of, and that is when you use hypochlorite of lime you have an accumulation of empty cans that you do not know what to do with. This in our own case is quite a problem. We have a pumping station that is located out in the lake. One of our workmen decided that one of our old cans needed disposing of, and was told to dispose of it, because it was old and uncertain in content. So he dumped it into the creek, and it killed many fish. We paid $100 to the State Conservation Commission as a fine for killing the fish. But in general liquid chlorine has proved very satisfactory with us, and we would not want to go back to the hypochlorite of lime.

MR. H. F. HUY (*by letter*): The writer has read Mr. West's paper with interest and he thinks it is very comprehensive. However, there are a few points on which he thinks Mr. West has misunderstood him in his previous explanation, as affecting the plant of the Western New York Water Company.

On page 442 where he states that the results are not comparable, due to the fact that we used liquid chlorine in the raw water and the sedimentation basin. The results we obtained were comparative due to the fact that, at that time, we were filtering 6,000,000 gallons of water daily and using 30 pounds of hypochlorite of lime in the effluent from the filters and obtaining satisfactory results. We obtained the same results in the same effluent by the use of 3 pounds of liquid chlorine. In both cases there was

no liquid chlorine applied to the raw water. Therefore the results are comparable.

The question might be raised as to why the liquid chlorine was more effective than the hypochlorite of lime in a greater ratio than is warranted by the greater percentage of chlorine in the solution. This may be somewhat accounted for by the fact that when you mix the hypochlorite solution and use only 30 pounds per day, it is probable that a considerable amount of the hypochlorite of lime may not show even 25 per cent of chlorine, and that the hypochlorite of lime no doubt deteriorates very rapidly; especially after the can has been opened, and the sterilizing effect is reduced.

The tests that we made covered a period of at least two months; therefore we were able to determine this more from a practical than a theoretical view point.

Recently the writer has heard a considerable amount of criticism in regard to a taste in the water, claimed it to be caused by the use of hypochlorite of lime, especially in places where water is taken from the Great Lakes, such as Toronto, Cleveland, etc. We have periodically observed a taste in this water due to dead algae, which taste is somewhat similar but not nearly as nauseous or as brackish as that produced by the use of hypochlorite of lime; but the general public has attributed this taste, whenever noticeable, to the use of hypochlorite if same is used by private or municipal water works. The writer understands that this has especially caused considerable objection lately in Toronto. Our experience in Niagara Falls and Buffalo is that you cannot use more than 5 pounds of hypochlorite of lime in the water of the Great Lakes without noticing a taste therefrom in the treated water. Compared with this, we can use 5 pounds per million gallons of liquid chlorine, which is practically equivalent to about 40 pounds of hypochlorite of lime, before noticing a taste, and then the taste is not nearly as objectionable as that produced by the use of hypochlorite of lime.

For the last five months we have been treating the raw water of Lake Erie at our Buffalo plant, with 1 pound of liquid chlorine per million gallons. The bacteria count in the raw water at our pumping station, which is located about 3 miles south of the southerly city limits of Buffalo, and the intake of which is located about 1½ miles out in the lake, varies from 200 to 1200 per cubic centimeter with turbidity ranging from 0 to 100. This latter turbidity is only obtained during a few months in the year. Generally speaking the

water is very clear. By treating this water with 1 pound of liquid chlorine per million gallons we are able to reduce the bacterial count to 20 per cubic centimeter with no indications of B. coli in 10 cc. sowings. Generally the raw water in the lake shows B. coli indications in 10 cc. sowings.

The writer is very sorry that Mr. West's paper does not show our results as compared with those of the municipal plant at Niagara Falls, as he thinks same should be included, for the reason that the water supply taken by the municipal plant is not taken from the shore, as is that taken by the water company, therefore its bacterial count in the raw water is generally about 2500, although there are B. coli indications in 1 cc. sowings. Their type of filter is a standard type of filter, but is ineffective in removing the B. coli or producing a count much below 200. To obtain a quality of water which competition with the private company has made them deliver, they have attempted to obtain results by the use of hypochlorite of lime, using as high as 4 pounds per million gallons, and at times in excess of this amount, and still not accomplishing as good a result as we do at the private company's plant. They also, very often, get a very noticeable taste in the water furnished to the consumer, and the municipal water works department has lately been subject to considerable criticism due to this trouble.

MR. C. A. JENNINGS (*by letter*): Mr. West's paper is a very thorough and fair statement of any argument on "hypo vs. liquid chlorine." When the manufacturers first made their claims that 1 pound of liquid chlorine would do the work of from 4 to 6 pounds of hypo, the writer was skeptical and thought that these were merely talking points for the salesmen. Judging from the experiences at Philadelphia and elsewhere with liquid chlorine after having had experience and data on hypo, it would seem that if anything these statements were really conservative.

The writer has seen a number of liquid chlorine installations and has been impressed with their simplicity and compactness. Some time ago he spent several months experimenting at the Bubbly Creek filter plant at the Chicago Stock Yards trying to find a suitable regulating valve for liquid chlorine. The problem was a hard one.

The automobile has replaced the horse for many purposes but has not eliminated the horse. The writer feels that liquid chlorine will

supplant hypo in many plants now using hypo, and that it will be installed in a large number of cities, not now using any disinfectant, in preference to hypo. However, he does not believe that hypo will be eliminated. It will probably be used for smaller installations, because of the smaller installation cost for the small and medium sized plants, and will be used to quite an extent for sewage, where the odor from the drums and the turbid solution will not be objectionable. He does not believe that all of the drawbacks laid to hypo are correctly placed. Many of the troubles laid to the use of hypo are really due to lack of attention; faulty design of the treatment plant; incomplete mixing of the solution; expecting from the use of hypo a greater removal of bacteria than is really practicable or necessary, and the adjustment of the dose to obtain this maximum removal.

MR. GEORGE A. JOHNSON (*by letter*): The writer has read Mr. West's instructive paper with great interest. Hypochlorite of lime will continue to be used in a large number of places, of course, but there seems to be no question that as a general proposition the liquid chlorine process is the better.

Briefly speaking, the advantages of the liquid chlorine process are not in the line of reduced cost, as compared with the hypochlorite of lime process, but in ease and convenience of application. The chemical is pure and concentrated in small containers, whereas hypochlorite of lime is bulky, varies greatly in its content of "available chlorine," and is troublesome to handle. The latter deteriorates in strength as soon as the containers are opened, whereas liquid chlorine in iron containers holds its original strength almost indefinitely. The space required for a liquid chlorine apparatus is exceedingly small as compared with the space required for storage of the dry chemical, and mixing and storage tanks for the solutions.

The writer is a believer in liquid chlorine, and thinks that the author has well stated the case in the closing paragraph of his paper:

> While in some instances liquid chlorine may prove more costly than chloride of lime, the regularity with which it can be applied, the more effective the action on pathogenic bacteria, the small, compact apparatus, and the absence of the odor of chlorine around the plant, recommend it as a satisfactory substitute for hypochlorite, having as it does all the advantages of the latter and only some of its faults.

MR. GEORGE C. WHIPPLE (*by letter*): Mr. West has given us a valuable contribution to the literature on water disinfection by the use of chlorine. Particularly interesting are the data as to the relative cost of disinfection with calcium hypochlorite and liquid chlorine. It would be a convenience for those who desire to study the subject further if the author would arrange the cost of the two processes in tabular form in some such unit as dollars per million gallons. As given in the paper it is a little hard to make the comparison.

It seems evident that both calcium hypochlorite and liquid chlorine may be relied upon to disinfect water supplies, and that the two processes are about on a par as to the efficiency and freedom from tastes and odors, provided that both chemicals are added to the water in proper amounts and with proper regularity. The advantages of liquid chlorine over calcium hypochlorite appear to lie in the field of economy and convenience. It is not clear that in all cases liquid chlorine is cheaper. Both chemicals probably have their special adaptations and with time these will become defined.

DISCUSSION

THE CROTON WATER SUPPLY, ITS QUALITY AND PURIFICATION

By George W. Fuller

A paper read at the January meeting of the New York section; printed in the Journal of the American Water Works Association, vol. 1, no. 1, at pages 135.

Mr. Alexander Potter (*by letter*): It is generally admitted that there can be no issue as to the desirability of filtering surface waters to improve their physical characteristics and sanitary qualities. In general this is also true of the Croton water. On the other hand there is a decided difference of opinion among engineers as to whether or not the filtration of Croton water is imperative at this time. It will be admitted that filtration will not materially decrease the death rate from typhoid fever in Manhattan and the Bronx. Since 1880, New York has successively occupied first, second, third or fourth place in the roll of honor for low typhoid fever death rates among American cities, in this regard eclipsing many cities that possess modern filtration plants. The typhoid fever death rate of New York City is now far below the number stated by so eminent an authority as Rudolph Hering as a number which would prevent the casting of any suspicion whatsoever upon the water supply.

The lessons to be drawn from the defeat of the filtration project as discussed by Mr. Fuller are important ones. Nevertheless, a project of such vast importance should be judged upon other and more scientific grounds and statements of facts than that one suggested by Mr. Fuller; viz., that "a comparison of the engineers mentioned above approving of the project with a list of those who have opposed it, is convincing," or, in other words, that the mere mention of the names of certain engineers as opposed to other engineers is sufficient to condemn or uphold a project irrespective of scientific facts.

In 1906 Mr. Fuller was retained by the city of New York to prepare plans for filtering the Croton water After exhaustive studies

had been made by him, including the installation and testing of an experimental filter, he recommended the installation of slow sand filters at the Jerome Park site. Concerning this plant Mr. Fuller states: "This project was pigeonholed, very likely because the panic of that year (1907) and the difficulty of selling bonds made public improvements of this character impracticable." Had the city officials at that time accepted the recommendation of the filtration engineers at its face value, then, according to the estimates of Mr. Fuller himself, the city of New York would have spent $5,000,000 needlessly. In table 7 presented by the author we find that the construction cost of a slow sand filter plant without coagulation is set down at $11,638,500, and with coagulation, at $10,753,700, as opposed to an estimate of $7,405,000 for a mechanical filter plant, the type of plant recommended by the author in 1912 when he was reëngaged by the city of New York as consulting engineer for the design and construction of a filter plant. This difference in cost of construction, together with the interest and sinking fund during the intervening period, amounts in round figures to the sum of $5,000,000. If mechanical filtration was advisable in 1912, it was in all probability as applicable in 1907 when Mr. Fuller recommended slow sand filters.

Is it not pertinent to inquire whether the defeat of the project in 1907 was due simply to the condition of the bond market, as suggested by Mr. Fuller, or to the doubt in the minds of the city officials having the project under consideration that the ultimate construction cost of the project would greatly exceed the estimates submitted by the engineer for this project, due in part, at least, to the excessive rates of filtration recommended? In fact, the estimate submitted by Hering and Fuller in 1907 for a slow sand filter plant was approximately $3,000,000 lower than the estimated cost of such a plant made by Mr. Fuller in 1911–12 when recommending mechanical filtration in place of the slow sand filtration approved by him in 1907.

Mr. Fuller criticises the city officials in no uncertain terms for their inconsistency. His exact language is:

> It is rather curious that a ten year long attempt to give the citizens of New York a drinking water supply of a quality such as is elsewhere demanded should have finally proven abortive. And even more curious that the same officials who had voted to give New York a proper drinking water should later with the same information before them reverse themselves, that a Board of

Aldermen, who but a short time before were considering a vote of censure on the executive department for their slowness in providing filtered water should a few months later repeal their ordinance and condemn the project.

Certainly we are justified in believing that some strong and convincing facts other than those mentioned by Mr. Fuller in his article must have been presented to the New York City officials to cause them to so change their decision.

It is therefore logical that we endeavor to secure an unprejudiced statement of the facts presented to the officials and Mr. Mitchel and to investigate the extent to which the water has since been improved by the simple and remedial methods favored by Mr. Mitchel.

To quote again from Mr. Fuller's paper upon this point:

The last chapter of this controversy was written on May 22, 1913, when Mr. Mitchel reported to the Board of Estimate his deduction that in his judgment hypochlorite would make our water safe, and that aeration would serve to remove from 50 to 75 per cent not only of the tastes and odors, but also of the color and turbidity from the water. With this he cast the vote which killed the project.

Statements by engineers should be precise and exact, and the author is open to criticism in stating that Mr. Mitchel invaded the field of the engineer and expressed his judgment as to the value of hypochlorite and aeration. Before finally acting upon this filtration project, Mr. Mitchel sat simply as a court and heard much evidence in reference to the efficiency of hypochlorite and aeration treatments. At this hearing Mr. Fuller stated that proper aeration might remove from 50 to 75 per cent of the objectionable taste and odors from the water. Basing his judgment upon such opinions as this Mr. Mitchel concluded that filtration at the present time, while highly desirable, was not imperative. In regard to the efficiency of sterilization with hypochlorite of lime, Mr. Mitchel had before him the statements made under oath by Mr. Fuller and also by Mr. George A. Johnson (who also contributed to this discussion) in the case of Jersey City vs. Jersey City Water Supply Company.

Jersey City was supplied with water from the Boonton Reservoir. The drainage area tributary to this reservoir is 121 square miles. The population on the watershed is 25,000. The drainage area of Croton water is 360 square miles and the population 25,000. In other words, the pollution from the tributary population is three times as great in the Boonton reservoir as in the Croton reservoir.

The storage in the Boonton reservoir was stated at the hearing by Mr. Johnson or Mr. Fuller to be 200 days storage. Mr. J. Waldo Smith stated that the Croton reservoir held nearly a year's supply. It is, therefore, evident that the opportunity for sedimentation in the Croton reservoir is greater than that in the Boonton reservoir. The alleged peculiar conditions of Croton water militating against successful use of hypochlorite of lime, therefore, existed to even a greater degree in the Boonton water, if indeed these peculiar conditions are at all important.

The testimony of Mr. Fuller is found in volume 9, testimony for defendants in court of chancery on reference McGee, N. C., page 5097:

Q. Which is the simpler process to handle and to manage in operation—filtration by this method or oxidation? A. This oxidizing process is by far the simpler to handle.

Q. In your opinion is this oxidizing process effective to remove the bacteria in the Boonton water so that it is pure and wholesome for drinking? A. Yes, sir.

Q. Is it reliable? A. Yes, sir.

Q. Is it safe? A. Yes, sir.

Q. What in your judgment is the propriety, or, is it in your judgment a proper method to adopt at the Boonton dam for the rendering of this water pure and wholesome for use at Jersey City? A. I think it is, assuming in my answer that it is the objectionable bacteria which it is the purpose to remove. I might add a word more, that is, that that qualification was intended to refer to the fact that this is not a substitute for filtration; it is not a process to remove mud or the coloring matter which we call vegetable stain, such as comes from decomposed leaves in swamps.

Q. You are assuming that the problem here is to destroy the objectionable bacteria, so that there should be no danger from infection or contamination from that source? A. Precisely.

Q. And destroy the pathogenic germs? A. Yes.

Q. And is it effective to do that thing? A. It is effective and safe.

Q. And reliable? A. And reliable.

Again Mr. Fuller testified on page 6685, volume 12, as follows, referring to the treatment of water with hypochlorite of lime:

Q. After this year's experience with this plant, what is your judgment of it as to its safety and its effectiveness for sterilizing the water? A. I think that this process produces a safe water and one which in its efficiency as a process compares very favorably, indeed most satisfactorily, in fact, with the best filter plants as regards both construction and operation of those filter plants. In other words, it meets the plan which is represented by the best practice in the art of water purification. I am speaking, of course, now with

regard to the removal of objectionable bacteria; that is the very point at which the process is aimed. . . . .

Q. What do you say as to the purity and wholesomeness of this water as delivered this past year through the operation of this process? A. In my judgment, throughout the year this water has been pure and wholesome as delivered at Jersey City.

Q. Has the removal of bacteria by this sterilization process been as efficient as could have been expected from a well and properly built filtration plant? A. Yes; I think it has been substantially as complete a removal.

Mr. George A. Johnson testified as follows on page 5181:

Q. In your experience, have you ever found from a surface water as uniformly a low count of residual bacteria as appears in this water, since the application of this method? A. No, sir, I haven't.

Q. What is the quality of this water, after this treatment, as to safety and potability, in your opinion? A. I think it is perfectly safe for all domestic and industrial uses.

Q. Is this method, in your opinion, reliable? A. Yes, sir.

Q. Is it safe? A. Thoroughly.

Q. Is it uniformly effective in its action? A. Yes, sir, always.

Q. In your opinion is this method suitable, or otherwise, to be applied to Jersey City water supply, for the purpose of rendering it safe and potable at Jersey City? A. I think it is in all ways thoroughly suitable and safe.

Q. Is this method, in your judgment, a practical method for continuous use, to keep this water pure? A. Yes, sir, it is.

Q. Is it as simple as would be a filtration plant, or as easily handled? A. Why, it is much simpler to manage than a mechanical filter plant or a sand filter plant.

In this now famous case Jersey City maintained that Boonton Lake received at times raw sewage from Dover, Boonton and Hibernia, and that the sewage from these towns must either be removed or purified, or possibly both, before the water supply system could be accepted by the city. Based on the expert testimony referred to, the courts held that chlorination rendered this polluted water pure and wholesome at all times and that the city could not compel the Jersey City Water Supply Company to construct the works wanted by the city.

The answer of Mr. Fuller, endorsed by Mr. Johnson, that additional information concerning the value of hypochlorite warranted them in modifying the strong and emphatic position taken by them in 1909, is inconclusive. Mr. Johnson in his discussion of Mr Fuller's paper goes so far as to state that as early as 1910 he set forth the limitations of the hypochlorite treatment. One of the limitations

mentioned is, "(2) Inability to remove bacteria which are imbedded in particles of suspended matter." At the same time and in the same paper, Mr. Johnson says, "Where waters are uniformly satisfactory in appearance, but open to suspicion as regards their content in bacteria, the use of the hypochlorite process alone in many cases may prove sufficient." Constrast this uncertainty in 1910 with the positiveness of the 1909 testimony.

The final verdict of the judge was not handed down until in 1910. It was influenced by the testimony of these two expert witnesses who were responsible for the design and operation of the hypochlorite plant at Boonton. Was there not some obligation resting upon these experts to submit a supplemental affidavit to the court notifying it of their change of position?

At the hearing before Mr. Mitchel, Mr. Fuller stated that, while hypochlorite was effective at Jersey City, it was not effective on the Croton supply, but he gave no scientific reason for his deduction. It is a fact that the results obtained at the Dunwoodie sterilization plant (placed in operation since the hearing before Mr. Mitchel) are vastly superior to the results obtained from the crude plant in operation prior to that time, and this notwithstanding that at the Dunwoodie plant there still remain imperfections in the rapid and thorough mixing of the sterilizing medium with the water.

It is interesting to note, moreover, from the discussion already brought out by Mr. Fuller's paper, that the micro-organisms in the water causing taste and odor have, according to Dr. Frank E. Hale, director of laboratories of the department of water supply of the city of New York, been reduced this past year more than 50 per cent by the simple expedient of drawing water from depth. When such a simple process produces such marked improvements in the water, can a layman be properly criticised for delaying a project which was admitted by the engineers as not imperative?

When this whole matter was up before Mr. Mitchel for final decision, it was urged by Mr. Fuller that filters were necessary because filters were the only practical means for the removal of tastes and odors which more seriously affect Croton water than any other water supply. Yet Dr. Hale tells us that by the simple expedient of taking water at 75 to 90 feet below the surface the water furnished consumers is 10° cooler and there is a reduction in the number of micro-organisms in the city of 75 per cent from 1911 to 1913, due largely to the employment of this simple expedient.

At this same hearing before Mr. Mitchel the writer asserted that the failure of the hypochlorite treatment in the removal of bacteria in the Croton water was due to the imperfect application of the chemicals. The accuracy of this statement of the writer's was challenged by the author and laughed at by other eminent experts present at the hearing as absurd. But what are the facts today? The author in his paper says that, in 1912, 20 per cent of the samples, the source of which is not given, showed B. coli in 1 cc., while Dr. Hale tells us that since the completion of the more perfect sterilizing plant at Dunwoodie only 3 per cent of the samples of the water as furnished consumers showed B. coli in 1 cc. in 1913, and none at all in 0.1 cc., and that there was a 95 per cent removal of B. coli against 90 per cent in 1912.

Mr. Fuller also argues for the immediate necessity of filtration because of the high rate of turbidity when the level in the reservoir is low; yet it was brought out in the hearing before Mr. Mitchel that the completion of the Ashokan Dam and the Catskill Aqueduct and the relatively low draft upon this new supply for a number of years should supply deficiencies in the Croton reservoir. In this manner for a number of years the low levels in the reservoir, which cause turbidity, will be prevented.

The author regrets the failure of the filtration project and says that it will interest the Association as an engineering question and "it will form the basis of an instructive comparison some years hence when filtration will be finally effected for the Croton water." The writer would suggest that it would be a much more interesting, and certainly a much more profitable discussion if the author would give us more specific information as to why, after an investigation in 1906–07 conducted by himself and his partner, Mr. Rudolph Hering, and costing the city some $50,000, he recommended that sand filters be adopted, whereas when employed a second time, in 1911, he reversed himself and recommended mechanical filters. Some good reason, not referred to in his paper, must have presented itself to him.

As exactitude of statement in engineering discussion is essential, it is interesting to compare the statement of Mr. Fuller and that of Dr. Hale as to pollution of Croton water existing at the present time. Mr. Fuller says:

3. The watershed contains some 13 miles of railroad track within 300 feet of the flow line, and 18 railroad bridges aggregating 1700 feet in length. The

sewage from the passenger trains enters the reservoirs practically raw, and may often contain pathogenic bacteria. So far, it has not been practicable to enforce proper sanitary control over the wastes from these railroad trains.

The difficulties of asserting authority and abating nuisance are considerable under existing laws, and make watershed protection harder than it should be.

4. Highway bridges, 19 in number, aggregating 4200 feet in length, discharge their wash into the reservoirs.

Dr. Hale in his discussion says:

All trains in passing over the watershed have their toilets locked during transit. Bridges over the reservoirs and streams are swept daily to remove the horse droppings, etc.

The facts stated by the writer are sufficient in his judgment to warrant any board in deferring action upon an undertaking which is so expensive and at the same time admitted as not imperative.

In the opinion of the writer, the author is not justified in reflecting upon those engineers whose convictions were at variance with him, or upon the city officials who voted to defer the construction of the filters for the present.

Mr. George W. Fuller (by letter): The comments of Mr. Alexander Potter on certain features of the writer's paper on the Croton water supply call for a few words in response.

Broadly speaking, Mr. Potter suggests that in the paper the author did not present the position of the opponents of the Croton filtration project, and that there are a number of arguments available against the building of this filtration plant which fully explain and justify its abandonment. An examination of the original paper, however, will readily show that this opposition was presented. On pages 170 and 171 the dissenting report of Mr. Frazee was abstracted at length. On page 173 we can find a reference to the Jersey City water supply case. In both cases the opposition on these grounds is answered, and it is not necessary here to repeat this answer.

Mr. Potter finds some fault with the condition that we know more today about the action and value of hypochlorite treatment than we did in 1909. At that time it was not evident, as it has been since, that the value of hypochlorite is limited by the conditions of its application; and that under some conditions, and such conditions obtain in the Croton water at times, the hypochlorite treatment is not fully dependable. Mr. Potter quotes some operation figures of the

Croton supply for the years 1912 and 1913 and deduces a conclusion that the greater efficiency of the Dunwoodie chlorinating plant accounts for the greater efficiency in the latter year. This greater efficiency is more properly to be attributed to a natural cause, the better quality of the raw water treated in the year 1913. The very essence of the limitations of the hypochlorite treatment lies in the fact that, while with fairly clear water, having relatively a small amount of microscopic organisms and organic matter, the treatment is highly efficient, with relatively impure water the treatment is relatively inefficient, not necessarily so as expressed as a percentage, but as measured by final effect. The Croton water was on an average in the year 1913 far superior in all properties to the average of the year 1912, and it is accordingly to be expected that the hypochlorite treatment should have been satisfactory. When the time comes, as it will in the course of years, that the Croton water is again largely polluted and contains much organic content and possibly greater turbidity, the effect of the hypochlorite treatment will be far less, and if it should happen that at that time the Croton water be polluted by typhoid bacilli, it is quite within the bounds of probability that a typhoid epidemic, perhaps of small and perhaps of large extent, may result. Such a danger is sufficient to warrant the expenditure of 25 cents per capita per year to avoid.

The assumption that the introduction of the Catskill water, with its works, would give the city such a wide margin of water supply that the Croton can be used to best advantage, and that low water in the reservoirs and unsatisfactory water cannot obtain, seems to the writer a rather rash one and not based on any evidence thus far developed. The best information available leads to the thought that the Croton supply must rest on its own bottom, even after the introduction of the Catskill.

Mr. Potter raises the question of the change in the type of filters recommended between the years 1907 and 1914. The reasons are to be found in the development of the art of mechanical filtration during these seven years. The writer feels in no danger of being accused of having been a foe to mechanical filtration. At the time of the early investigations into the Croton water two fair-sized mechanical filters of modern type had been built, namely, the Little Falls plant and the Hackensack plant. While these plants had been entirely successful, the writer did not feel that the art had attained sufficient standing at the time of his 1907 report to war-

rant the adoption of mechanical filtration for this particular water. In the interval since 1907 modern mechanical filtration has reached such a position that the writer feels no hesitation in recommending it for any waters whatever where the desired results could be obtained by this method at a less total annual cost than with sand filters.

Finally, the writer wishes to take issue with the statement in Mr. Potter's second sentence that:

> There is a decided difference of opinion among engineers as to whether or not the filtration of the Croton water is imperative at this time.

It is only necessary to point out in the original paper the words on page 174:

> It has never been represented as absolutely imperative.
>
> * * * * *
>
> But it is certainly desirable that a city the size of ours should have a pride in doing these things, and it should have a pride in drinking a water for which it need not apologize as reasonably safe at most times and fairly decent-looking at most times.

And this is the position taken by practically all of the engineers who have investigated the question. It certainly adds nothing to our knowledge for Mr. Potter to attempt to prove that this filtration is not imperative.

DISCUSSION

PRESENT DAY WATER FILTRATION

By George A. Johnson

A paper read at the March meeting of the New York section and printed in Journal of the American Water Works Association, Vol. 1, No. 1, at pp. 31–80.

Mr. John H. Gregory: The author has presented a paper which contains much of interest to water works engineers and superintendents interested in filtration, and there is much in the paper with which the speaker is in hearty accord. There are, however, some phases of the subject on which the speaker holds somewhat different views from those of the author, among which may be mentioned the questions of the cost and difficulty of securing sites for slow sand filters and those of the cost of both slow and rapid sand filters.

The author states:

> It is true, on account of the much greater area required, the cost for land is far greater in the case of slow sand filtration systems than for rapid sand systems. Roughly, other things being equal, land will cost twenty times as much for a slow sand filter installation as for a rapid sand plant.

There is but little question that, under ordinary conditions, the cost of land for slow sand filters will exceed that for rapid sand filters, owing to the larger area required, but that it will amount to as much as "twenty times" that for slow sand filters is open to question. Those who have had experience in acquiring land for water works projects know that, even if only a small piece of land is required on which to locate the works, but that this piece of land is a portion of a much larger tract, the purchaser might often as well buy the whole tract of land as to buy only a small portion of it. Thus it may readily be that, in acquiring a site for rapid sand filters, much more land would be actually purchased than needed simply for the plant. It may be that the area required for the construc-

tion of a slow sand filter plant will be twenty times that required for a rapid sand filter plant but that the land will cost twenty times as much does not necessarily follow.

In discussing further the question of site the author states:

> Furthermore, in large projects, it is often difficult conveniently to locate a site for slow sand filters, while for a rapid sand filter plant it is a relatively easy matter as a rule. If it is necessary to go a long distance in locating an extensive and suitable area of land for a slow sand filter site there is incurred a large expense for a conduit to bring the filtered water to the city.

The inference might be drawn from this that it has been exceedingly difficult to secure sites for large slow sand filter plants, but the history of many of the plants which have been built will hardly bear out this inference.

In commenting on some of the plants which the author mentions in the table on page 69 the speaker might say that he has been personally connected with seven out of the fifteen plants mentioned and is familiar with the reasons which led to the selections of the sites on which these works were built. It is, of course, necessary to have land on which to build filters, whether of the slow or rapid sand type, but in the selection of a site local conditions are often a very important factor.

At Albany, New York, for example, practically the first ground available on which filters of either type could be built and which could be purchased at a reasonable price, was that on which the slow sand filters were actually built, just north of the city line. It happened that there was another tract of land a little nearer to the existing water works pumping station, to which the filtered water was to be delivered, where it would have been possible to build either slow or rapid sand filters. To have acquired land there, however, for either type of filters, would have been very expensive. The site on which the filters were built had another advantage in that the intake there would be further away from local sources of pollution; at Albany the Hudson River is tidal; the sewage from the city was and still is discharged into the river without treatment and on flood tides there is often an upstream current which carries some sewage with it. It will be seen then that other factors than simply area of land alone may have a bearing.

At Pittsburgh, Pennsylvania, as far as the speaker is aware, no difficulty was found in securing a site for the slow sand filters which

plant is one of the largest in the world. The filter plant is located directly across the Allegheny River from the Brilliant pumping station, from which most of the water used in the city is pumped. It is true that it was necessary to build conduits under the river to bring the filtered water to the pumping station, but the case would have been the same if rapid filters had been built instead, for, if the speaker's memory is correct, the best site on which filters of either type could have been built was that on which the slow sand filters were constructed.

For the four slow sand filter plants in Philadelphia mentioned by the author, namely, Torresdale, Upper Roxboro, Lower Roxboro and Belmont, and of which the speaker had charge of the design, no trouble was experienced in securing suitable sites.

As regards the Lower and Upper Roxboro filter plants, local conditions were of the greatest importance in that it was necessary to utilize existing reservoirs as settling basins, as well as existing pumping stations and pipe lines. Somewhat similar conditions existed with reference to the Belmont plant although in this case there was no reservoir which could be utilized as a settling basin.

The Torresdale slow sand filter plant is the largest single plant in the world, and if difficulty had been experienced in securing suitable sites for such works it would naturally be expected to have occurred here. Such was not the case, however, and the plant was built inside the city limits. It is true that the plant was located some distance up stream from the closely built-up part of the city, and that a conduit about 2½ miles in length was constructed through which filtered water is delivered to the Lardner's Point pumping station, but it was good judgment on the part of the city authorities to locate the works where they did.

The Delaware River at Philadelphia is tidal and is polluted by the discharge of sewage from the city, and it was to avoid pollution as well as to secure a site that the plant was built as far upstream as it was. It might be added further that the city has already constructed a small sewage disposal works just below the Torresdale filter plant, where sewage is treated and the effluent disinfected before discharge into the river, in order to guard against raw sewage from the nearest point reaching the intake of the Torresdale filters. Had rapid sand instead of slow sand filters been built at Torresdale there is no question in the speaker's mind but that such a plant would have been built as far upstream as were the slow sand filters.

One might fancy possibly that trouble would be experienced by the city of New York in securing sites for filters. Such is not the case. Over ten years ago the commission on additional water supply, in its investigations for an additional water supply for New York City, looked into the question of filter sites not only for the additional supply but also for the Croton supply. Sites were found where slow sand filters could be built in close proximity to the existing Croton Aqueduct, and sites for slow sand filters were also found and surveyed where the additional supply could be filtered along the line of the proposed new aqueduct. Some years later the department of water supply actually prepared detailed plans for a slow sand filter plant for the Croton supply, on a site located in New York City, namely, in the east basin of Jerome Park Reservoir, the construction of which was suspended pending a decision as to the filtering of the supply. In the case of New York City it is not a question of going a long distance and building an expensive conduit to get a filter site, but rather a question of going a long distance and building an expensive conduit to get water.

At Cincinnati, Ohio, the rapid sand filter plant, which is the largest of its kind in operation in the world, was built well upstream above the city where plenty of land was available for either rapid or slow sand filters. The filtered water is discharged through a long conduit to the main pumping station from which it is pumped to the reservoirs in Eden Park. This plant was built for the future as well as for the present and it was good judgment to locate the plant as far upstream as it is.

At Columbus, Ohio, the rapid sand filters were built at some little distance upstream above the city. It was a case here of going upstream to get out of the flood zone, although sufficient land for either rapid or slow sand filters was available nearer the city. At the point where the plant was finally built there was sufficient land for either rapid or slow sand filters. In acquiring the land for this particular plant it was found that it would be about as cheap to acquire the whole tract of land on which the works were built as to acquire only so much of the same as would be needed for the plant alone.

Perhaps enough has been said to point out that factors other than the area of land alone have to be taken into account, for slow as well as for rapid sand filters, in selecting a suitable site.

The author also considers, in the table on page 69, the cost of

construction of different types of filters. It is exceedingly difficult to compare satisfactorily the costs of construction of different plants, even where the fullest information regarding the same is available. Those who are not well posted as to the history of some of the plants cited in the table may possibly be misled as to the cost of building both slow and rapid sand filters if they accept the figures of the author without full knowledge of local conditions.

One of the features which very materially affects the cost of such works is the total reservoir capacity provided, that is the combined capacity of the settling basins and of the clear water reservoirs. To illustrate: The rapid sand filter plant at Little Falls, New Jersey, which, in the author's table is the most expensive one cited, and which cost $15,000 per million gallons daily capacity, has a coagulating basin capacity of 1.3 hours and a filtered water reservoir capacity of 2.6 hours, or 3.9 hours total reservoir capacity. At Columbus, Ohio, the rapid sand filter plant, which the author states cost $13,000 per million gallons daily capacity, the next to the highest in cost cited, has a settling basin capacity of 12 hours and a filtered water reservoir capacity of 8 hours, making a total reservoir capacity of 20 hours, or five times as much reservoir capacity as that of the Little Falls plant. If the reservoir capacity of the Little Falls plant had been approximately that of the Columbus plant the cost of construction of the Little Falls plant would have been materially increased over that given by the author. Again, the New Orleans rapid sand filter plant might be cited, which has 35.2 hours total reservoir capacity, or practically nine times as much reservoir capacity as that of the Little Falls plant. Other factors which affect the cost of construction are the character of the raw water, the rate of filtration, the character of the construction of the works, etc.

In his reference to the Albany slow sand filter plant the author gives its capacity as 20,000,000 gallons daily. The Albany plant as originally built before the pre-filters were added, had a capacity of 15,000,000 gallons daily. The addition of the pre-filters increased the capacity of the plant very materially so that at the present time the capacity is probably in the neighborhood of 28,000,000 gallons daily. If the capacity is taken at 28,000,000 instead of 20,000,000 gallons daily the cost of the plant would be about $14,300 instead of $20,000 per million gallons daily capacity as given by the author.

The Philadelphia slow sand filter plants were expensive plants to build. They differ in one way from many of the other filters of

the same type that have been built in that, underneath the filter floors and carried up all around the sides of the filters, is a layer of puddle. This item alone materially increased the cost of construction. The Lower Roxboro and Upper Roxboro plants were built on high ground in an isolated section several miles from the nearest railroad, and the cost of delivering materials to such plants was higher than would ordinarily be the case.

In the cost of the Lower Roxboro plant the author did not include the cost of the Lower Roxboro reservoir which was built many years before, and which supplies settled water to the filter plant. Again, a similar condition exists at the Upper Roxboro filter plant with regard to the settling basin. The New Roxboro reservoir was built some ten years earlier than the filter plant, and the author has not included its cost in the cost of the filter plant. Strictly speaking, the costs of the reservoirs should be included in the costs of these two plants so that the figures would be comparable with the costs of the other slow sand filters cited.

The Philadelphia plants were built during a régime of very high prices, and to use the costs of construction of these plants to indicate the reasonable cost of slow sand filters may be very misleading except to those who are familiar with the early history of these works, and who are aware that the costs were high and that the plants could be duplicated at less cost.

The largest slow sand filter plant under construction in America at the present time is at Montreal, and, when completed next year, will have a capacity of 60,000,000 United States gallons daily. The total cost of the plant, on the basis of the lump sum contract prices, including the low lift pumping station, will be about $22,600 per million gallons daily capacity. Deducting the low lift pumping station the cost will probably be about $21,000 per million gallons daily capacity.

It would have been interesting if the author had cited the cost of the slow sand filter plant which was completed at Toronto about two years ago. This plant has a capacity of 48,000,000 United States gallons daily, assuming one-sixth of the filter area to be held in reserve, and based on a rate of filtration of 6,000,000 United States gallons per acre daily, the rate for which the plant was designed. The cost of the plant, omitting the low lift pumping station, was only about $12,700 per million gallons daily capacity.

In considering the weighted average cost of slow sand filters given

by the author, namely $32,600 per million gallons daily capacity, it may be well to bear in mind that the Montreal plant will cost only about $21,000, that the Albany plant cost about $14,300 and the Toronto plant only $12,700 per million gallons daily capacity.

In referring to the cost of rapid sand filter plants the author cites the Columbus plant as costing $13,000 per million gallons daily capacity. This plant was designed and built under the speaker's direction and is a water-softening as well as a rapid sand filter plant. The cost of this plant was given in great detail in a paper[1] read by the speaker some years ago. The speaker is not informed as to what items the author included in arriving at the cost of the Columbus plant, but in the speaker's judgment the Columbus plant, considered as a rapid sand filter plant alone, cost nearer $15,000 than $13,000 per million gallons daily capacity, the figure given by the author.

Another rapid sand filter plant which the author might have cited is that at Toledo, Ohio, the cost of which was published in the *Engineering Record*, November 26, 1910. Part of the plant was built for a capacity of 60,000,000 gallons daily, although the present capacity of the works is considerably less. Including only such items as are chargeable to the filter plant proper the works cost about $14,500 per million gallons daily capacity.

Another rapid sand filter plant which might have been cited is that at Grand Rapids, Michigan. The plant was completed inside of the last two years and has a capacity of 20,000,000 gallons daily. The cost of the plant, as given to the speaker by the Grand Rapids officials last year, including such items as are chargeable to the filter plant proper, was $16,300 per million gallons daily capacity.

In December, 1912, the city of New York received bids for a rapid sand filter plant to be located at Jerome Park reservoir and having a capacity of 320,000,000 gallons daily. The speaker is more or less familiar with the plans for the proposed Jerome Park filters as he served as one of a commission of engineers appointed by the board of estimate of New York City to report on the same. Taking the lowest bid received and adding to it the cost of the buildings and other necessary work, the Jerome Park filter plant, which would have been the largest rapid sand filter plant in the world, would have cost about $18,400 per million gallons daily capacity. When the plant is built, and it is greatly to be hoped it will be built soon,

[1] *Trans. Am. Soc. C. E.*, vol. lxvii, 1910.

the actual cost will probably be in the neighborhood of $20,000 per million gallons daily capacity, as much of the excavation for the plant has already been completed.

The author gives the cost of the Cincinnati rapid sand filter plant, which has a daily capacity of 112,000,000 gallons, as $11,400 per million gallons daily capacity, and states that the cost of the large, plain sedimentation basins is not included. At Cincinnati there are two large settling basins to which the raw water from the Ohio River is pumped. The water is first settled in these two basins, and is then delivered to the coagulating basins at the filter plant. There is no question in the speaker's mind but that the settling basins are part of the filter plant at Cincinnati, but just how much of the cost of the same should be chargeable to the filter plant may be a question. Mr. J. W. Ellms, the superintendent in charge of the filters at Cincinnati, in a paper printed in the *Journal of the Association of Engineering Societies* in January, 1912, states:

> The settling reservoirs, which have a capacity of 330,000,000 gallons of available water, are in part a portion of the water purification plant, although they also serve the purpose of storage basins and were designed for such a use quite as much as they were for sedimentation purposes.

The two settling basins cost $1,521,000, or about $13,600 per million gallons daily capacity of filter plant. Adding this cost to that of the filter plant would give a total cost of $25,000 per million gallons daily capacity. As the settling basins serve as storage reservoirs also it may be reasonable to charge the filter plant with perhaps only half their cost. On this assumption the cost of the settling reservoirs chargeable to the filter plant would be $6,800 per million gallons daily capacity, thus making the total cost of the filter plant $18,200 per million gallons daily capacity.

Still another plant which the author might have cited, and among the best in the country, is that at New Orleans, which has a capacity of 40,000,000 gallons daily. Including only such items as are chargeable to the filter plant proper the cost of the New Orleans plant was about $30,200 per million gallons daily capacity.

The weighted average cost of the Columbus, Toledo, Grand Rapids, Cincinnati and New Orleans rapid sand filter plants, is $18,600 per million gallons daily capacity, while the author gives a weighted average cost for rapid sand filters as $12,100. In other words, the weighted average cost of the five plants just cited, all of which are

in operation and which are among the best in the country, is over 50 per cent higher than the weighted average cost given by the author.

The speaker has but little further to say on the subject of cost except that, in his judgment, the weighted average costs as given by the author are too high for slow sand filters and are too low for rapid sand filters. Similarly the fixed charges on the costs of construction would respectively be too high for slow sand and too low for rapid sand filters.

The speaker is not presenting any brief for slow sand filters. The rapid sand filter is more flexible than the slow sand filter and in the majority of cases in the United States is better adapted to the purification of water than is the slow sand filter. The slow sand filter has done and is still doing good work in this country, and the present status of water purification is, to a large extent, due to the introduction of the slow sand filter.

Mr. George C. Whipple (*by letter*): The writer believes most thoroughly in mechanical filtration. He also believes in sand filtration, and does not agree with Mr. Johnson that this method is becoming obsolete.

It is perfectly true that there have been more mechanical filters introduced during recent years than sand filters. This is wholly proper and natural, for, as he states, a majority of American cities use waters for which mechanical filtration is better adapted than sand filtration, namely, turbid waters and colored waters. It is also true that the possibility of disinfecting water readily and at low cost by means of liquid chlorine or calcium hypochlorite has somewhat broadened the field of the mechanical filter. These facts are well known to all sanitary engineers, most of whom, however, will not admit that sand filters are obsolete. To do so would be to ignore the filtration practice of a very large part of the world.

Mr. Johnson has given an excellent historical review of the subject, and he has done well in emphasizing the very great need of careful supervision of all filter plants, whether sand or mechanical.

The section of his paper devoted to the relative costs of slow sand and rapid filtration is incomplete, misleading and illogical. His figures are of little use to engineers, and it is to be hoped that they will not be quoted in such a way as to mislead laymen unfamiliar with the subject.

In the first place, no statistics of cost are given, but merely the rate of cost per million gallons capacity. The reader, therefore, has no opportunity of ascertaining in what manner the computations are made. In some cases also the figures are quite evidently unreliable, as the footnotes to the tables themselves indicate. In the second place, figures are given for only fifteen filter plants out of several hundred which are now in operation. In the third place, the final comparison of cost is based on weighted averages, which unduly emphasize the costs of the plants of larger capacity. The very great range in the few costs that are given emphasizes the need of great caution in using them.

A comparison of the cost of filtration by the two processes is, of course, a matter of interest, but it must be a general, rather than a specific interest, for in any particular case the true comparison is between the cost of the two processes applied to local conditions.

Again, the statement that slow sand filtration is out of its element where chemicals are required is absurd. One only has to study the cost and results of filtration at Washington, D. C., and at Springfield, Massachusetts, to learn that chemicals may be economically applied with great benefit to waters filtered by slow sand processes.

Another statement to which exception should be made is:

> The hygienic efficiency of water filtration processes measured by the reduction in typhoid fever may be said to be about 70 per cent.

The hygienic efficiency is actually far greater than this, being nearer 100 per cent than 70 per cent, that is to say, practically all of the water-borne typhoid fever is eliminated. It is well known that typhoid fever is transmitted in many other ways than by public water supplies, and in measuring the efficiency of water filtration these should be entirely left out of the count. The author is quite right, however, in saying that both sand and mechanical filtration, if properly operated, are capable of preventing the spread of water-borne diseases, and from a hygienic standpoint, there is little to choose between the two methods.

Quite as much depends upon the manner in which the filters are operated as upon the type of filter installed. Poor operation of mechanical filters is likely to do more damage than poor operation of slow sand filters. The greatest difference, however, is not so much dependent upon the type of filtration as upon the size of the plant. Generally speaking, the large plants receive a much higher

degree of supervision than smaller plants, and one of the problems which sanitary engineers have most at heart at the present time is that of securing more efficient operation of small filters. Until better supervision can be secured, it is wise to utilize the natural purifying influences that come with long storage to as great an extent as possible. From a hygienic standpoint storage is of greater benefit to a small water works than to a large water works system.

In conclusion, the writer feels that most water works superintendents will sympathize with King James, referred to by Mr. Johnson, preferring shoes that are easier for the feet to those that pinch and produce corns and bunions. It seems to the writer that it is high time for engineers to cease talking about the relative merits of sand filtration and mechanical filtration, in fact most sanitary engineers have long since done so, and recognize that both sand and mechanical filtration have their proper place in water works practice.

MR. P. A. MAIGNEN: The speaker has had no time to read the paper before this morning and has just run through it and finds two passages which give occasion for saying a few words. The author, on page 39, states:

> The residual turbidity in the effluent of this preparatory process is caused by suspended matter in a state of fine sub-division. This matter, when applied to slow sand filters, penetrates deeply. . . . . The penetration of suspended matter into the beds is sometimes as great as 10 inches.

Now it may be asked: Is this penetration of fine mud into the interstices of the sand a good or a bad thing? Is not the filtration likely to be of better quality? Do not the filters work longer without cleaning? At the origin of slow sand filters it was usual in London and Paris to run raw water on to the filters to fill up the interstices of the sand at the surface and make that once celebrated thing which was called Schmutzdeke. The only objection that can be made to the deep penetration is that when the sand has to be cleaned more of it has to be handled, but then it goes longer without cleaning so that the cost per million gallons of water filtered is not materially different, and if anything, the filtrate is probably better. It was to obviate this penetration that an artificial Schmutzdeke was designed of fine fibre such as asbestos fibre, or of other fine filtering material, such as coke or charcoal, to be deposited on the surface of the sand at the beginning of an operation as the mud of the raw water used to be applied.

The first work done in the way of preliminary filtration in this country was done in Philadelphia, at the Lower Roxboro Plant, after a very elaborate and prolonged study in the laboratory and experimental plant, and also in the testing plant of the city of Philadelphia at Spring Garden Street. This study has clearly established the fact, for the first time in the history of filtration, that it would be possible to obtain a speed of 6,000,000 gallons per acre per day from slow sand beds instead of 2,000,000 or 3,000,000, previously obtained. The preliminary filtration was then found to remove from 60 to 75 per cent of the suspended matter and of the bacteria, and of course rendered the work of the final filter easier and safer. A second system of preliminary filtration was installed at Belmont Station of the city of Philadelphia water purifying system. Preliminary filtration has been applied with considerable success and rendered possible the effective work of the filter plants designed for South Bethlehem and Lancaster.

Too much should not be expected from preliminary filtration. It was not intended to retain the fine suspended matter referred to above. Its very words show that it was to retain the coarsest materials, and by one of those unexplained phenomena the bacterial efficiency of this coarse filter has been extraordinary, averaging fully, when properly conducted, 75 per cent. If the chemical treatment of water is objected to, there is no other way known to the speaker to make the slow sand filters effective, when the water is charged with the fine suspended matter in question, but to use an artificial Schmutzdeke on the sand itself.

The author of the paper, on page 79 refers to:

> That slow sand filters, without the aid of costly preparatory treatment, cannot efficiently purify such waters as those of the Hudson River at Albany, the Delaware River at Philadelphia, the Potomac River at Washington, and the Allegheny at Pittsburgh. And even with preliminary filters there are cases where not only the appearance of the slow sand filtered water is at times unsatisfactory.

This can be done by means of an artificial Schmutzdeke, but special design of the filter beds is to be resorted to for the proper distribution of same as was done at Lancaster and Bethlehem.

MR. W. C. HAWLEY: The results given for the Pittsburgh filter plant are extremely interesting and probably explain the reason why so little has been printed regarding the operation of that plant.

The conditions in the Allegheny River are extremely difficult to handle, and while in the light of the state of the art at that time, doubtless good judgment was used in deciding upon a slow sand filter plant, it is at least probable that, if the problem was to be considered today, mechanical filtration would be adopted.

It may prove of interest to give, by way of comparison, results obtained by a mechanical filter plant filtering water obtained from the Allegheny River only a short distance, perhaps 1000 feet, above the intake of the Pittsburgh plant. This plant was built in 1909–10 by the Pennsylvania Water Company.

The Pennsylvania Water Company was supplying at that time a population of about 80,000 people and large industrial establishments, and was pumping about 10,000,000 gallons a day. The company had been obtaining its supply for some years from filter cribs located in the bottom of the Allegheny River, which have been described so frequently that it is not necessary to go into that matter at this time. The filter plant was designed to take advantage of the purification which the cribs would perform, thereby reducing the work to be done by the filter plant. This not only reduced the cost of the filter plant, but our experience has demonstrated the advisability of the use of similar cribs, to a certain extent at least, in filter plants similarly located. The advantage of these cribs is that they give a water of more or less uniform alkalinity, always sufficient to react upon the coagulant, and a material reduction in bacteria, turbidity and color. This is because a considerable proportion of the water taken from the cribs comes from an underground source and is not merely filtered from the river.

The filter plant is of the ordinary mechanical type with an ultimate capacity of 20,000,000 gallons a day. It was originally equipped for 10,000,000 with two extra filter units provided, which have since been equipped, making the capacity of the plant at the present time 12,500,000 gallons a day. The plant is located upon the hill back of the pumping station at a distance of about one mile, and at a total elevation of about 620 feet above the river. The water is delivered into two sedimentation basins of a capacity of about 1,500,000 gallons each. Coagulant is added as water enters the basins, and more coagulant may be added at the baffle wall half way across the basin, or as the water flows from the basin to go to the filter beds. Hypochlorite of lime may be added at the baffle wall or at this last point. As the water from the cribs is very low

in turbidity, it has been found advisable to add some raw river water. This gives softer water, and the small amount of turbidity thus added aids sedimentation.

This plant was put into operation in July, 1910. During July and August the gauges, controllers, etc., were tested and regulated, but it was not until September that regular records were kept. Hypochlorite was not added until November, and has been used regularly since that time. A comparison of the results with those obtained at the Pittsburgh plant is interesting. The average number of bacteria per cubic centimeter in the water as it entered the sedimentation basins for the last four months of 1910 was 5200, ranging from a monthly average of 350 in September to 14,130 in December. The average number of bacteria per cubic centimeter in the filtered water for the four months was 78, with monthly averages ranging from 15 in September to 114 in December, with maximum counts of about 250. The colon bacillus was found in 10 out of 21 samples of raw water, and in only 2 out of 289 samples of the filtered water. Alum used averaged 0.82 of a grain per gallon, and the hypochlorite 0.036 of a grain per gallon.

For the year 1911, the average number of bacteria per cubic centimeter in what few river samples were examined was 16,870, and in the water as it entered the sedimentation basin 4718. In the filtered water the average for the year was 14, with monthly averages ranging from 62 in January to 3 in July. Colon bacillus was found in 661 samples out of 771 of the water as it came to the sedimentation basins, and in 17 out of 1047 samples of the filtered water examined. The average coagulant for the year was 0.92 of a grain per gallon, and the hypochlorite 0.041 of a grain per gallon. The average amount of water pumped per month was a little over 250,000,000 gallons.

For the year 1912 the results were about the same as for 1911.

During the first two years of operation it was, of course, necessary to experiment, in order to determine the most efficient method of operating the plant. The improvement is shown by the detailed figures which follow for the operation of the plant for 1913:

DATE 1913	HYPO. CALCIUM, GRAINS PER GALLON	SULPHATE OF ALUMINA, GRAINS PER GALLON	PER CENT WASH WATER USED	PARTS PER MILLION, TURBIDITY				PARTS PER MILLION, COLOR				BACTERIA PER CUBIC CENTIMETER						GALLONS DELIVERED PER MONTH
				Average		Highest day		Average		Highest day		Average			Highest day			
				Mixed	Filt.	Mixed	Filt.	Mixed	Filt.	Mixed	Filt.	River	Mixed	Filt.	River	Mixed	Filt.	
Jan.	0.061	0.97	2.4	59.4	0	150	0	29.6	0	45	0	5,756	3,305	4	14,350	10,350	22	255,690,863
Feb.	0.058	0.95	2.3	16.4	0	150	0	17.2	0	35	0	2,779	1,317	6	5,800	3,100	15	240,743,223
Mch.	0.061	1.00	2.5	38.5	0	150	0	27.5	0	45	0	4,500	2,379	3	12,000	7,000	7	262,342,093
Apr.	0.056	0.86	2.2	5.4	0	10	0	17.5	0	23	0	2,523	1,078	2	6,300	3,750	4	260,978,518
May	0.057	0.83	2.1	7.8	0	40	0	21.6	0	35	0	9,692	4,719	3	31,000	22,780	10	280,862,782
June	0.058	0.85	2.2	27.4	0	400	0	22.9	slight	40	slight	17,773	13,943	3	45,000	36,500	8	277,832,302
July	0.064	1.03	2.2	41.1	0	300	0	33.9	slight	45	slight	15,531	9,537	6	30,500	23,000	20	287,026,221
Aug.	0.060	0.93	2.1	10.6	0	60	0	23.9	0	40	0	17,213	12,319	3	31,500	25,000	6	297,387,037
Sept.	0.062	0.99	2.3	9.6	0	35	0	26.5	0	42	0	22,371	17,175	4	45,000	38,500	15	269,650,365
Oct.	0.062	1.04	2.3	17.5	0	60	0	29.2	0	50	0	12,428	9,926	3	33,000	31,500	7	270,310,052
Nov.	0.060	0.98	2.4	18.6	0	125	0	24.6	slight	48	0	4,117	1,938	1	19,300	12,500	3	250,492,179
Dec.	0.050	0.70	2.0	2.6	0	10	0	14.4	0	25	0	984	561	3	1,600	1,900	9	249,716,454
Average.	0.059	0.93	2.3	21.2	0			24.1	0			9,639	6,533	3.4				

During the year 1913 the colon bacillus was found in 473 out of 531 samples of the river water examined, and in 784 out of 1065 samples of the water as it entered the sedimentation basins. It was found in 2 out of 1062 samples of the filter water and in none of 1038 samples of tap water which were examined.

J. N. CHESTER: The speaker always feels grateful to any one who will prepare and arrange such tables and such a volume of statistics accompanied by intelligent comments as Mr. Johnson has furnished in this paper. If, however, in the compilation of this, the attitude has been assumed that there is a conflict between slow sand filters and rapid sand filters and the cudgel has been taken up on either side by the writer, the speaker is not in accord with his attitude. It is the speaker's belief that every situation presents its own problems, which the engineers of this country are able to solve, and that the information we have in this paper will assist greatly in the solution of such problems.

The speaker is very glad that Mr. Gregory has furnished additional data and that he has corrected such statements as he feels are erroneous. Cities are differently situated; they have different waters to handle; and with Mr. Gregory the speaker agrees that a rapid sand filter is much more flexible and therefore adaptable to a much larger number of situations than is a slow sand filter. The cost of rapid sand filters as given by Mr. Gregory for average results, are more in accord with the speaker's experience on the larger and better built plants than the figures that appear in the paper. Of course slow and rapid sand filters have in many instances been built at as low as $10,000 per million gallons capacity, and may be found lower than that; but when you analyze the elements that have entered into those plants, the reason is plain. We always feel when we give an estimate of less than $15,000 per million gallons that we must cut something out to do it, especially if we are going to build a larger sized plant, which ordinarily costs more than a small plant per million gallons, because the large plants have more frills, they have more to cater to from the side of ethics and civics and other things of that sort. When, fifteen years ago, we were building mechanical filter plants we thought of nothing but the tub and the clear water basin, and that was generally very small. Then we talked about building them at a cost of from $8,000 to $10,000 per million gallons. Later we got to storing larger quan-

tities of clear water and acknowledged the necessity of sedimentation basins. Probably all of you remember when we built without sedimentation basins; and now we are building more expensive filters using concrete instead of steel or wood; and thus the cost of the mechanical filters has been going up instead of down.

The speaker will not attempt to take up the cudgel for either slow sand or mechanical filters. The matter of location and land has been pretty thoroughly discussed by Mr. Gregory, and the speaker heartily concurs in his statement that they are governed by circumstances and may be one thing in one place and another thing in another place.

There are, however, some things in this paper to comment on here that do not relate to the cost but to other matters. It has been pretty well admitted that slow sand filters are not adaptable to extremely turbid water; and when the selection of slow sand filters was made in Pittsburgh, it was considered that Pittsburgh was just about on the edge of the zone of turbidity that would permit slow sand filters; and, as has been the case in other instances, it was found afterward that the preliminary tests and determinations that were made prior to the building of that filter did not reveal subsequent high peaks, although they got high peaks that year. And, of course, you know the outcome is that other arrangements have been made to keep down those peaks. The statement that we have 2000 p.p.m. more turbidity there is correct; but even those turbidities are small as compared with rivers further west. Mr. Montfort could testify to some higher turbidities they have in his neighborhood. At Kansas City, St. Joseph, and other points along the Missouri River you will find what sedimentation basins must do, and then if you reflect a few minutes you will find that the design of the plants in those neighborhoods should be somewhat different from the design of the plant in Pittsburgh where the turbidities are but 2000 and below instead of 10,000 and sometimes above as in the case of the western waters.

The comments on the use of lime, or the necessity of using lime, to prevent the CO_2 and consequent red waters, is underestimated by the author, at least in some districts. In our Pittsburgh districts at least, and in many others, there are periods of the year when the addition of lime even though the alkalinity does not require it, is an absolute necessity to prevent excessive CO_2 in the water and consequent red water results. These are annual occurrences, and not occasional ones in the Pittsburgh district, but they are occasional in many other districts.

MR. JAMES M. CAIRD: The writer regrets that he was unable to be present when this valuable paper was presented. The paper treats with great detail the progress made in this country in the art of water purification. It would be interesting to know exactly what is being done abroad, and if slow sand filtration is as popular as formerly, or if there has been a change to the American or mechanical filters.

There has been very little advancement in the constructive features of slow sand filters in this country. The improvements have been chiefly in the method of removing and washing the sand. At Wilmington, Delaware, the sand is washed in the beds, and up to the present time this method has been a success at this plant.

At the present time there are few slow sand filters in this country where the method of operation has not been changed. The changes consist of larger settling basins, pre-filters, coagulation and sterilization.

In the colder climates the slow sand filters are very difficult to operate owing to the formation of ice on the beds; this of course requires a greater construction as well as operating cost.

It is true that the bacterial efficiencies decrease during the colder months, but the most trouble is with the slow sand filters which become readily, "air bound."

In this country there are about 480 filtration plants with a combined capacity of 2,565,000,000 gallons daily, 450 or 93.7 per cent are of the American or mechanical type and furnish 1,745,000,000 gallons or 68 per cent of the filtered water.

Originally the great difference between the two methods of filtration was the use of a higher rate and coagulants by the American or mechanical filters. At the present time about all the slow sand filters are using coagulants and thereby are able to operate at a higher rate, so that they are following the example of the American method.

Albany having had considerable trouble in operating the slow sand filtration plant, pre-filters have been installed. A sterilizing agent is now in use and if the writer has been correctly informed a coagulant is used for at least part of the time.

At Rensselaer (East Albany) New York, population 11,000, there is a mechanical filter operating on Hudson River water, the same supply as is used at Albany, but on the Troy side of the river and therefore containing more sewage than the Albany unfiltered water.

This plant uses sulphate of alumina as a coagulant and also calcium hypochlorite.

Table showing bacterial efficiency and typhoid fever death rate, per 100,000 population, Rensselaer, N. Y.

YEAR	EFFICIENCY	TYPHOID RATE
	per cent	
1910	98.75	28.0
1911	99.84	18.7
1912	99.96	9.3
1913	99.71	0.0
Average	99.56	14.0
1900–05		67.5

Typhoid fever reduction 79.3 per cent.

The Washington case was most peculiar in that both methods of filtration were tested experimentally, the results showing that the American or mechanical process did the better work, yet in the face of these facts a slow sand filter was installed. At the time great objections were raised against the use of coagulants; however, it has been found that satisfactory results could not be obtained without the use of a coagulant, and this method is now in use in connection with the slow sand filters.

In 1901 there was an inquiry held by the United States Senate Committee on the District of Columbia on the purification of the Washington water supply, at which hearing great stress was laid upon the fact that at Elmira, New York, they used mechanical filters and that there were ten deaths from typhoid fever the year before the filters were installed and eleven deaths the year the plant was placed in operation or an increase of 10 per cent in the death rate.

The first year the Washington plant was in operation there was no great reduction in the typhoid fever death rate and a very extensive investigation was made to learn the cause.

Table showing typhoid fever death rate per 100,000 population at Washington, D. C. and Elmira, N. Y.

YEAR	WASHINGTON	ELMIRA
1907	36.0	28.0
1908	39.0	30.7
1909	33.0	33.5
1910	25.0	26.9
1911	22.0	13.3
1912	23.0	15.9
Average	29.6	24.7

These results show that during the same period the Elmira typhoid fever death rate averaged 16.6 per cent less than that at Washington.

The Elmira situation is rather peculiar in that there are about one thousand wells in use, and the water company is unable to close these wells. The State Board of Health in a recent examination of fifty wells reported that 65 per cent contained B. coli-communis. When the history of a typhoid fever case shows that a patient used water from a certain well, the local board of health have the water examined, and if B. coli-communis is found, the well is closed. The wells are not examined until such time as they fall under suspicion.

The water supply of Elmira is divided as follows: 25,000 using filtered water, 5000 using well water and 5000 using a mixture.

The Elmira typhoid fever death rate for the year 1913 was 10.5 per 100,000 population. During the six years 1907–12 there was a total of fifty-three deaths in Elmira from typhoid, seven or 13.2 per cent claimed to have used nothing but well water, while twenty or 37.7 per cent of the deaths, were among cases imported to the local hospitals.

The average number of bacteria in the Washington filtrate was 54 per cubic centimeter, while the Elmira average was 40 per cubic centimeter or 26 per cent less. The Elmira unfiltered water contained 10,907 bacteria per cubic centimeter while the Washington contained 1930 per cubic centimeter, or 82.4 per cent less. During the past year the Elmira filtered water contained an average of nine bacteria per cubic centimeter.

There is no statement in Mr. Johnson's paper as to the media used for the bacterial work. At all plants with which the speaker is connected, the efficiency of the plants is based upon the bacterial growth on gelatin for forty-eight hours as 20°C.

If there ever were two places where American or mechanical filtration should have been installed they are Philadelphia and Pittsburgh. The Pennsylvania Water Company, Wilkinsburg, Pennsylvania, supplies several of the suburbs of Pittsburgh. American or mechanical filters are used, the supply being obtained from filter cribs in the Allegheny River and also river water direct. This water is thoroughly aerated, sulphate of alumina being added before aeration, after which the water passes through a coagulation basin and calcium hypochlorite is added to the water before it enters the filters.

Table showing results, Wilkinsburg, Pa.

YEAR	BACTERIA PER CC.		REMOVAL	CHEMICALS	
	Raw	Filtered		Alumina	Hypo
			per cent		
1911	4,051	36	99.12	0.93	0.035
1912	7,953	31	99.62	0.92	0.044
1913	6,266	4	99.64	0.92	0.058
Average....	6,090	24	99.61	0.92	0.046

The filtered water is always free from color and turbidity, aeration and coagulation removing the iron.

The Baltimore County Water and Electric Company, Baltimore, Maryland, operate a slow sand and also mechanical filters on the same water at their plants located at Avalon, Maryland. As far as the writer knows, this is the only place in this country where the same unfiltered water is used for both style filters.

The American filters remove practically all of the color and turbidity, which is not the case with the English filters.

Average results four years, 1908–11, Avalon, Md.

BACTERIA PER CC.			B. COLI 1 CC. SAMPLES		
Raw	Eng. Filtration	Am. Filtration	Raw	Eng. Filtration	Am. Filtration
			per cent	*per cent*	*per cent*
2,662	38	24	63.6	3.12	1.72

From reading Mr. Johnson's paper, one would be led to believe that there never had been any trouble with any filters of the American or mechanical type. During the past few years there have been some changes in the type of strainer systems, and the speaker knows of three plants where the new strainer system has given out within a short time after being placed in operation, and where trouble has been experienced in getting a uniform washing of the beds. It is the speaker's opinion, that the old method of strainer heads is to be preferred to the use of the wire screens placed over the gravel.

There is no question but that the American or mechanical filters are able to treat any water which can be treated with slow sand filters, and that mechanical filters can treat water which cannot be treated by slow sand filters.

Sulphate of alumina is the best coagulant, and can be used for all waters. Sulphate of iron and lime do not give good results with a water containing high vegetable colors.

Mention is made of the socalled "red water plague" and that it is thought to be more pronounced where sulphate of alumina is used as a coagulant. The amount of sulphate of alumina used as a coagulant has been greatly reduced since the hypochlorite process has come into use. The use of calcium hypochlorite tends to still further reduce the amount of free carbonic acid in the water and hence any action from this cause is reduced. The speaker has had great success from the use of hydrated lime in absorbing carbonic acid, and it is also of great value in making up the deficiency in alkalinity.

No matter which type of filter is in use, it must have proper care or its operation will be a failure.

MR. J. W. ELLMS (*by letter*): Mr. Johnson has clearly set forth in this paper the development of the art of water filtration, and the important position which it holds in the field of general sanitation. He presents statistics of a convincing character, showing the greater adaptability of the system of rapid sand filtration to the waters of the United States, than that of slow sand filtration. With his views on this matter the writer is in entire accord, and believes that no other logical conclusion than that stated by the author can be drawn from the facts.

The effect upon the health of a community of the substitution of a filtered water supply for one that had been used unfiltered, and which was known to be badly polluted, is no more strikingly shown than in the case of the city of Cincinnati, where filtered Ohio River water was introduced in the latter part of 1907 in place of the raw river water. The writer has compiled some mortality statistics for a period of six years before and after the introduction of filtered water, and believes they may be of interest in connection with this paper.

The accompanying table (marked table 1) gives in detail the actual number of deaths, and the rate per hundred thousand of population for a number of the more common diseases, and for all causes, for a period of thirteen years. Some of the specific diseases listed are probably in part water-borne, such as typhoid fever, diarrhoea, enteritis and dysentery; others may be so disseminated, while some of them are probably not transmitted by water at all. As the year 1907 was one in which unpurified Ohio River water, both from the

TABLE I

Number of deaths and rate per 100,000 of population in Cincinnati, Ohio, from all causes and for certain specified diseases before and after the introduction of a filtered water supply

	UNFILTERED WATER														FILTERED WATER											
	1901		1902		1903		1904		1905		1906		1907		1908		1909		1910		1911		1912		1913	
	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000	Total Deaths	Rate per 100,000
Typhoid Fever	182	55.3	206	62.1	150	44.7	270	78.0	155	44.4	239	67.9	157	44.4	64	17.9	46	12.8	21	5.8	43	11.4	28	7.3	24	
Diarrhea and Enteritis	359	109.1	173	52.1	386	114.9	506	146.3	528	151.3	516	146.6	279	78.6	419	117.1	378	104.8	449	123.5	365	96.6	334	86.2	321	80.6
Dysentery	49	14.9	29	8.7	24	7.1	27	7.8	21	6.0	22	6.3	30	8.4	9	2.5	11	3.2	5	1.4	7	1.9	11	2.8	11	2.8
Pneumonia	456	138.6	425	128.0	440	131.0	631	182.4	594	170.2	505	143.6	419	118.0	423	118.2	382	105.8	388	106.6	288	76.2	303	78.3	609	153.0
Tuberculosis Lungs and Larynx	755	229.5	675	201.7	804	239.3	920	266.0	900	258.0	920	261.3	858	241.8	869	242.8	860	238.2	912	250.5	876	231.7	856	221.0	889	223.2
Diphtheria and Croup	69	21.0	78	23.5	63	18.7	38	11.0	78	22.4	77	21.9	56	15.8	54	15.1	38	10.5	28	7.7	48	12.7	60	15.5	53	13.3
Whooping Cough	17	5.2	14	4.2	16	4.8	4	1.2	44	12.6	11	3.1	15	4.2	28	7.8	21	5.8	24	6.6	16	4.2	27	7.0	50	12.6
Scarlet Fevers	24	7.3	51	15.4	37	11.0	26	7.5	73	20.9	10	2.8	5	1.4	31	8.7	14	3.9	13	3.6	71	18.8	38	9.8	20	5.0
Measle	45	13.7	33	9.9	19	5.7	37	10.7	5	1.4	61	17.3	19	5.4	53	14.8	2	.6	65	17.8	10	2.6	34	8.8	67	16.8
All causes	6155	1871.0	5744	1730.0	6201	1845.0	7038	2034.0	6534	1872.0	7195	2044.0	6414	1807.0	6449	1801.0	5921	1640.0	6330	1739.0	6225	1649.0	6453	1663.0	6734	1691.0

TABLE 2

Average death rates per 100,000 of population, Cincinnati, Ohio, and the percentage increase or decrease from certain specified diseases, and from all causes for periods between 1901 and 1906, both inclusive, and 1908 and 1913, both inclusive.

	RATE		AVERAGE PERCENTAGE	
	1901–1906 Unfiltered water	1908–1913 Filtered water	Increase	Decrease
Typhoid fever	58.7	10.2		82.6
Diarrhoea and enteritis	120.0	101.5		18.5
Dysentery	8.5	2.4		71.8
Pneumonia	149.0	106.4		28.6
Tuberculosis (lungs and larynx)	242.6	234.6		3.3
Diphtheria	19.8	12.5		36.9
Whooping cough	5.2	7.3	40.4	
Scarlet fever	10.8	8.3		23.1
Measles	9.8	10.2	4.1	
All causes	1899.3	1697.2		10.6

old and the new water works' intakes, was supplied to the city, as well as filtered water during the last two months of the year, it may be omitted when making a strict comparison of death rates for the two periods.

The reductions in the death rates in the filtered water six-year period, 1908–1913, from those in the unpurified water six-year period 1901–1906, are given in the accompanying condensed table (see table 2). In each disease, except whooping cough and measles, there has been a reduction in the rate, ranging from 3.3 per cent to 82.6 per cent, these diseases being tuberculosis of the lungs and larynx, and typhoid fever, respectively. For all causes of death there has been a reduction of 10.6 per cent. In typhoid fever the reduction has been most marked, with dysentery next in order of the diseases listed. Increases in the rates are shown only in the case of whooping cough and measles. The net reduction in the death rate for the group of diseases listed which constitute 32.9 per cent of all the causes for deaths in the first period, is practically 21 per cent. The reduction in deaths from this group of diseases had the effect of lowering the death rate from all causes by 6.9 per cent. Since the net reduction in the rate from all causes is 10.6 per cent, it is evident that about two-thirds of the reduction resulted from fewer deaths from the diseases listed in this group.

While there is no doubt that water-borne diseases have tended during the past six or seven years to reduce the total death rate in Cincinnati, other sanitary improvements have also played an important part. The education of the public in matters of sanitation must eventually have an effect upon the death rate from disease; but this effect is bound to be gradual and would fail to show the marked reduction in the rate exhibited in Cincinnati following the first year of use of filtered water. The conclusion that a purified water supply has reduced the total death rate in Cincinnati seems to be reasonable.

MR. GEORGE W. FULLER (*by letter*): Mr. Johnson's interesting and instructive paper points to a conclusion with which the writer is in general accord, namely, that sand filters are less satisfactory for the vast majority of water purification projects in the United States than is mechanical filtration. The former have been pushed into fields where their accomplishments have developed well-defined shortcomings in point of efficiency or economy or both.

In making the above statement it is to be clearly recognized that there are some exceptions to all rules, and in this regard the legitimate scope of sand filters probably has a field, limited as it is, from which other forms of water purification are not likely to drive them out. Nevertheless as the field of water purification has broadened so as to include the muddy water supplies from surface streams the applicability of mechanical filters has asserted itself more and more strongly. For those supplies requiring coagulant in order to bring about satisfactory purification, there is no room for doubt as to the superiority of mechanical filters under all ordinary circumstances.

Twenty years ago sand filters were used in treating a few fairly clear waters along the Atlantic seaboard. Then all water works men were timid and most engineers were afraid to advise filtration for the heavily clayladen waters of the South and Middle West. This was the time when the Providence filter tests to decolorize the local water were under way, and when the late Mr. Hermany was projecting his elaborate tests for demonstrating the practicability of mechanical filters in purifying the muddy Ohio River water. For several years water purification accomplishments were confined largely to exhaustive scientific tests into the merits and demerits of different types and arrangements. Mechanical filters prior to that time had had considerable ingenuity displayed in their design from the standpoint of mechanical arrangement, but hygienically,

their standing was predicated on careful tests at Providence, Louisville, Pittsburgh, Cincinnati and elsewhere.

When the choice of the type of filter arose at Washington, there was a great agitation on the part of the local medical profession against the use of coagulating chemicals and against the hygienic efficiency of mechanical filters based on their accomplishments in practice. So far as scientific studies carefully conducted on the two types of filters were concerned, there was no room then for deciding that either type possessed any decided advantage over the other. Each would be satisfactory. But when it came to rating the standing of the two types of filters upon the basis of the influence which plants of each kind had produced upon the death rate of cities where they had been installed, both European and American evidence gave the advantage to sand filters.

The splendid record of achievement by mechanical filters during the past dozen years or more changes that evidence materially, in that the accomplishments in reducing the death rates in the case of mechanical filters compare most creditably with corresponding data upon sand filters. That is, the mechanical filter has emerged from the test-filter-and-laboratory-demonstration style of evidence upon which to rest its credibility, and it stands today on its record of successful service as the prevailing type of filter in the United States in the treatment of water supplies when due regard is given both to efficiency and economy.

To the writer's thought, the two types of filters are entitled to equal standing in point of efficiency when each filter is properly built and operated, as should always be the case.

Some may find fault with Mr. Johnson's conclusion as to the comparative hygienic efficiency as shown by typhoid fever death rates in communities served by the two types of filters. The basis of this would be, of course, that the two types of filters do not necessarily deal with the same type of raw water and that the water consumers in the different cities are not subjected to the same general sanitary conditions, some of which, rather than the quality of the public water supply, are substantial factors in explaining the prevalence of typhoid fever.

In some measure a similar criticism might be made as to the relative costs of filtration in different places, where there are known to be differences in the costs of labor and materials and in other local conditions affecting cost. Whether construction costs represent fair profits to the builder, which should always be the case, is another point which should not be taken for granted.

However, considering the whole story along broad lines, as is the obvious intent of the author, there seems to be no sound basis for taking serious exception to his conclusions, which essentially are "that in the efficient and economical solution of the vast majority of water purification problems in the United States, the rapid sand filtration process is superior to the slow sand process."

MR. CHARLES B. BUERGER *(by letter):* The selection of the type of filter most suitable to any particular water, under such conditions that neither slow sand nor rapid sand is immediately ruled out by obvious considerations, forms, for each locality, a problem in itself; sometimes this is a difficult, sometimes an easy one to decide. Generalizations drawn from a number of plants must be taken with much caution, as the differences of conditions, design, local high or low costs of construction and operation, make comparisons difficult. Averages are still more unreliable.

We find on page 69 of Mr. Johnson's paper a table of first costs. These are no doubt representative, but there are many well-known plants running away from these averages. Among them may be mentioned:

Slow sand plants, double filtration	*per mgd.*
Queen Lane, Philadelphia, Pa. (75 mgd.)	$25,000
Montreal, P. Q., Canada (60 mgd. Under construction)	25,000
New York, N. Y. (320 mgd. Projected)	38,000
Rapid sand plants	
Steubenville, Ohio (6 mgd. Under construction)	22,000
Evanston, Ill. (12 mgd. Under construction)	17,000
Jackson, Miss. (4 mgd. Under construction)	17,000
Niagara Falls, N. Y. (16 mgd.)	16,000
New Orleans, La. (Carrolton plant. 40 mgd.)	40,000
Toledo, Ohio (34 mgd.)	17,000
Flint, Mich. (8 mgd.)	18,000
New York, N. Y. (320 mgd. Projected)	23,000

While the Cincinnati cost for a rapid sand filter may for any particular projected work be a better guide than the New Orleans cost, it is equally true that the Queen Lane or the Montreal cost may be a better guide than the Torresdale. Operating costs, too, must be considered with reference to the local conditions. For instance, the 1911–12 cost per million gallons of $4.01 at Washington, D. C., includes a pumping station cost of $1.24, leaving only $2.77 for the cost of filtration proper.

While emphasizing the needs of special consideration for any new case, the writer feels compelled to endorse Mr. Johnson's conclusion

that the usual proper decision will be in favor of rapid sand filtration. And particularly it should be recorded that even where the total annual charges, including capital and operating costs, are slightly less for a slow sand plant without chemical treatment, a proper business judgment will lead to a reservation of the excess investment. A higher cost of construction is not justified if it saves alone its interest in later operation charges; there must be a recognition of the removal of this useful capital from other fields of service and its potential earning power or service value in these other fields.

Mr. Johnson's reference to the difficulties which have been experienced with the Philadelphia Torresdale filters brings up a feature worthy of comment. The Torresdale preliminary filters were the first of their type, and there was no precedent to indicate, except in a general way, what their design should be. The successful Little Falls filter was based on fifteen years of indifferently successful trial with filters of the same principle, and after most elaborate scientific studies at Louisville and Cincinnati. A scrubber or preliminary filter designed in 1902, after fifteen years of use of preliminary filters, may show markedly improved results.

The differences between this Torresdale design of 1907 and the Montreal design of 1910 indicate possible lines on which better results might be obtained.

	TORRESDALE	MONTREAL
Maximum filter head	4.5 feet	12 feet
Thickness sand bed	12 inches	30 inches
Size sand (effective)	0.8 to 0.9 mm.	0.5 to 0.6 mm.

A limiting feature in the design of the Torresdale preliminary filters arose out of a peculiar local situation. Mr. Fred C. Dunlap, in 1907, chief of the Bureau of Water, and designer of this plant, found that his predecessor had purchased the raw water pumps without any intention of building or making any provision for these preliminary filters. He was working on the assumption that he could install water meters and cut in half the necessary water supply. The available pump head was thus 5 feet less than originally contemplated, and the filters were then designed to squeeze within this insufficient head. Much of the weakness of this plant may be attributed to a political rather than an engineering cause.

After all has been said, however, a vote by engineers who have worked on this plant as to proper treatment for this Delaware water, would be unanimously in favor of coagulation. The combination

of occasional coagulation with the present equipment may eventually be found to make a highly satisfactory plant, even on the basis of total annual charges.

MR. THEODORE A. LEISEN: It seems to the speaker that the fullest possible discussion of this paper would be highly advantageous to the Association, and particularly along this question of comparative costs. Mr. Gregory has very ably discussed it and has given us a great deal of additional information. It is hoped there will be further discussion, whether written or otherwise. The matter of costs of filter construction is open to the same line of error that was referred to the other day in connection with comparison of rates of different cities. There are so many elements entering into the thing that it is very difficult to avoid being misled unless all of the various factors are thoroughly understood. For instance, the original Louisville filter, if we eliminate the pumping stations and some other elements that might strictly be considered part of the filter plant, would stand at roughly speaking about $20,000 per million gallons, and possibly over that. That is somewhat higher than any of the others mentioned here, it includes a larger clear water basin than the average. There is a recent addition to filters now nearing completion. But if the cost were given offhand without understanding the matter it would stand at about $5000 per million gallons; so that any comparison without having the thing thoroughly understood would be misleading.

Regarding the turbidities, our record of the year is not here; but our turbidities at Louisville went up as high as 6000 p.p.m. last year, while 1000 is quite a common occurrence; and those waters could not be dealt with with a slow sand filter. In that case a mechanical filter is absolutely necessary.

It is unfortunate that, in so many of the discussions as to types of filter, too much prejudice seems to get into the question on the part of a number of people who have taken the thing up in recent years. There is a field for both the slow sand filter and the mechanical filter, and it is purely a question of judgment in each particular instance as to which one is to be used; but the matter ought to be discussed without any passion or prejudice whatever. Mr. Gregory's discussion brought that out and showed that he was looking at it from a purely fair-minded point of view.

MR. ROBERT SPURR WESTON: The speaker read over Mr. Johnson's paper with a great deal of interest, and the considerable time

required was well spent. Mr. Johnson has approached the subject from the standpoint of twenty years' experience, and has collected a vast amount of data which will be invaluable to water works operators and constructors from now on. The first reading of the paper left the impression of an argument in favor of mechanical filters; also the impression that the field in which the slow sand filter is operable is being rapidly diminished, and ultimately slow sand filters will disappear from use and mechanical filters will take their places. In other words, sand filters will pass out of use just as have Cornish engines.

Now, much as the speaker commends Mr. Johnson's paper, he cannot avoid discussing the other side of the question, and hopes that he has had broad enough training and experience, and sufficient acquaintance with all phases of the water purification problem, to be considered a practitioner in the field of water purification, rather than a partisan in favor of one of the two types of filters mentioned.

Each locality has its problem and should attempt its own peculiar solution. Undoubtedly, many slow filters were built and installed where rapid filters should have been chosen. Pittsburgh and Washing, D. C., are cases in point, and which have occurred in the writer's practice, but there are other cases where slow filters are not only more economical but more efficient than mechanical filters, and some of these cases are where high rates of filtration may be employed without detriment, because it is obvious that the cost of slow filters per million gallons decreases rapidly and inversely with the rate of filtration.

Generally speaking most engineers who are competent in the field of water purification, that is, those who have studied the problem for a long time in connection with many types of waters, are agreed that mechanical filters are best where the color is over 50 parts and the turbidity over 30 parts per million, or where there are unusual fluctuations in the character of a stream, which ordinarily is but slightly colored or turbid. Again, there are other cases where the water is so clear that there are no nuclei to start the coagulation of the applied chemical, upon which coagulation the efficiency of mechanical filters depends. To use mechanical filters in these cases may necessitate the addition of clay or other suspended matter to produce an artificial turbidity, or the use of an excessive amount of coagulant, so that the coagulant will precipitate by virtue of its large mass.

Before this paper was written the speaker made some studies of the comparative costs of slow sand and mechanical filters for presentation at a town meeting, and came to the conclusion that an

average cost of $14,500 per million gallons for mechanical filters, and a cost of $100,000 per acre for slow sand filters were good average figures. These figures are higher in the case of mechanical filters and lower in the case of slow sand filters than given by Mr. Johnson. In Mr. George W. Fuller's report on the Montreal Water Supply, dated July 22, 1910, the cost of sand filters was estimated at $33,840 and mechanical filters $21,091 per million imperial gallons daily capacity. The cost of slow sand filters per million gallons varies with the rate as the following table, assuming covered filters and appurtenances to cost $100,000 per acre, shows.

Rate of filtration mgd.	*Cost per mgd.*
10	$10,000
6	16,667
5	20,000
4	25,000
3	33,333
2.5	40,000

The cost of mechanical plants generally varies with the character of the water, and the writer believes the estimates in the following table represent the best practice in plants of moderate size. The costs include the necessary subsiding and coagulating basins; also small filtered water basin or pump-well.

Character of water			*Cost per mgd.*
Turbidity		or color	
0 – 100	or	0 – 25	$14,000
100 – 300	or	25 – 75	16,500
300 upwards	or	75 upwards	18,500

The above costs are higher than those of the largest and best plants constructed under favorable conditions, but lower than those of plants where unusual conditions prevail.

A mechanical and a slow sand filter, each of 1,000,000 gallons daily capacity, designed and constructed under the speaker's supervision during 1913, cost $16,000 for the mechanical and $18,000 for the slow sand plant. The cost of engineering for the mechanical filter was unusually high and the slow sand filter was in connection with a deferrization plant, where the costs included a coke trickler, 15 feet high and 30 feet in diameter, and where the filter operated at 10,000,000 gallons daily rate.

In the paper under discussion many references have been made to the hygienic efficiencies of plants treating waters which have been

disinfected with chlorine, and in many cases these have been compared with waters which have not been so treated. The cost of sand filtration depends upon the rate. In the early days, as will be remembered, slow filters were designed at rates of 2,650,000 gallons per acre per diem, and less, this rate being the German official rate of 100 vertical millimeters per hour. If bleaching powder be used to sterilize the effluent, there is no reason why this rate cannot be raised much higher than 6,000,000 gallons per acre, which is the maximum in ordinary present day practice.

Apart from the cost and efficiency factors in some cases, the speaker is in hearty agreement with the conclusions of Mr. Johnson's paper, namely that the mechanical filter is an efficient and reliable sanitary machine, one that will reduce the death rate due to water-borne diseases. It is true that the zone in which slow filters are used is narrowing, while that in which mechanical filters are used is broadening, but the speaker still contends that there is still a field for the slow filter, namely, where clear waters have to be purified and where local conditions make the cost of water furnished by the slow filter less. In comparing the efficiency and economy of the two types, one should use the same basis. One should not compare the efficiency of filters where the effluent is sterilized with those where no sterilizing chemicals are used.

Mr. James W. Armstrong: Some of the speakers in making their comparisons have given the cost of mechanical filter plants at prices from $15,000 to $20,000 per million gallons, and one of them suggested that in future the cost would probably be increased rather than decreased. The speaker does not believe that the added refinements which seem necessary in the larger plants need materially increase their cost per million gallons. With the proper design and arrangement of the various parts, a saving can be made in large plants which will more than offset the added cost of mechanical devices, as they are generally small in comparison with the total cost of the plant.

The filter plant now being constructed for the city of Baltimore is to be equipped with all kinds of operating and regulating devices, and its total cost, exclusive of real estate and legal expenses, will be about $1,400,000 which is a little over $10,900 per million gallons, For the sake of comparison with other filter plants, the speaker would like to state that the Baltimore plant has 32 filter units, having a combined normal capacity of 128,000,000 gallons, supported

by groined arches above filtered water basins having a capacity of about 2,500,000 gallons, a mixing chamber of nearly half an hour's capacity, two coagulating basins with a combined capacity of three hours, two covered filtered water reservoirs with a combined capacity of about 15,000,000 gallons, a head house containing a completely equipped laboratory, and a complete mechanical equipment, an intake shaft and pumping station, containing electrically operated centrifugal pumps having an aggregate capacity of 160,000,000 gallons, two earth dams, one of which is to be faced with concrete for forming the storage basin for the wash water, and two larger concrete wash water tanks. The entire filters are to be covered with a building. The superstructures of all buildings, including the gate houses, eight in number, are to be built of brick laid in cement mortar and covered with green tile roofs.

MR. JOHN C. TRAUTWINE, JR.: The speaker draws some personal satisfaction from Mr. Johnson's paper, which implies that slow sand filtration may not, after all, be the Alpha and Omega of the art, and particularly from his figure 2, which shows that there are, at present, about 12,000,000 persons supplied with filtered water in the United States, whereas, in 1899, not much more than about one-tenth of that number were so supplied. The paper (and especially its fig. 2), seems to give him the melancholy satisfaction of saying: "I told you so."

During the speaker's chiefship of the Philadelphia Bureau of Water (1895–99), there was no filtration of the Philadelphia water; and the City Fathers refused all appropriations for extensions and improvements. The Delaware water was polluted by the city's own sewage, and the Schuylkill water by the drainage from a densely populated mining and agricultural district with numerous cities and towns. After every rain, the Schuylkill water, for the first few days, was little better than liquid mud; and this was succeeded, a day or two later, by coal dust from the anthracite regions, making a tumblerful of Schuylkill water look like a tumblerful of ink.

Filtration was actively discussed, but there was no thought of giving us the benefit of expert advice. Rapid (so-called "mechanical") filtration was well to the fore, disputing the supremacy of the orthodox slow sand filtration, which was disputed also by numerous other filtration devices.

Recognizing his inability to decide off-hand between the claims of these several systems, especially in view of the fact that each

city and each river furnishes a problem of its own, the speaker urged that two of the smallest of our six stations, one on each of our two rivers, be made a practical experimental filter plant, composed of units representing the several approved systems of the day, and furnishing water, not merely for experiment, but for the actual supply of the districts served. This would not only have demonstrated the advantages of filtration as applied to our water, and improved the supply to the districts served, but would also have enabled us to decide between the claims of the conflicting systems. This, however, was far too "scientific" a procedure for the City Fathers, who, in response, demanded plans and estimates for filtration plants sufficient for the entire city.

With our engineering force consisting of three draftsmen, and one chief draftsman, the speaker set about responding to this demand, submitting plans involving the general adoption of slow sand filtration; but (still recognizing the need of further light upon the subject) provided for a rapid filtration plant in connection with one of the stations, viz., that at Queen Lane; and in this respect, he was followed by the experts of 1899, Messrs. Rudolph Hering, Samuel M. Gray and Joseph M. Wilson, who, in their plans, provided for a rapid filtration plant in connection with the Spring Garden or East Park System.

But, when the final decision was made, the new administration, in whose behalf all appropriations had been held up, decided peremptorily against the consideration of the rapid filtration system; and the city thereupon proceeded to the construction of its present $30,000,000 plant, composed, at first, entirely of slow sand filtration beds; but, these proving inadequate to the demand, were later supplemented by preliminary filters.

Mr. Johnson's figure 2 confirms the speaker's statement, made to the city councils during his chiefship, that the science and art of filtration were then in their infancy, and shows that the present tendency is to the increased use of rapid filtration. It thus indicates that it might have been well for us to take a little more time to make sure that we were right, before going ahead.

The refusal (already mentioned) of the city councils to appropriate money for extensions during the speaker's administration, and the open boast of local patriots that the appropriations were being deliberately held up in favor of the succeeding administration, led him to suspect that the cost of our works (quoted by Mr. Johnson) may have been higher than was absolutely necessary.

MR. ROBERT E. MILLIGAN: The speaker has noted one or two matters during the discussion that seemed to him to be in corroboration of his own experience in mechanical filtration. This matter of costs as one may gather from the discussion is one very difficult to accurately define. Frequently the speaker is asked to make an approximate estimate in advance. Some of these inquiries come from engineers themselves for information that can be easily gotten by the manufacturer from the very many filter plants that have been installed in the United States and other parts of the world.

As a matter of fact, the speaker believes that Mr. Chester is in error in saying that large plants are not necessarily less expensive per million gallons than small ones; and Mr. Armstrong has mentioned the fact that Baltimore is an instance of very low cost. In this connection it must be remembered that there are very few cases as yet of mechanical filtration plants of over 25,000,000, or say 50,000,000 gallons, to compare any costs on; but probably the lowest price ever offered for a mechanical filter plant of great size was the recent offer in connection with Jerome Park, New York City, when the difficulties of labor and construction are considered; and this cost actually was approximately $15,000 per million gallons. Such plants as the one at Hackensack and Little Falls, New Jersey, ranging above 30,000,000 gallons capacity, have cost in the neighborhood of $15,000 per million gallons but, since they are very limited in subsidence, if compared are greatly in excess of the Jerome Park costs. Commonly small plants ranging from 1,000,000 to 10,000,000 gallons, or 1,000,000 to 5,000,000 gallons will present very high costs if equipped with the large areas of subsidence common to large filter plants as they generally carry with them machinery which increases the unit price very materially, such as blowers and wash pumps, and this cost is out of all proportion in the very small unit. Plants can be, and have been, designed of great efficiency anywhere from 5,000,000 to 10,000,000 gallons at about $10,000 per million gallons; at least that is the speaker's experience in the matter, and he is satisfied that similarly designed large plants would be considerably less per million gallons.

In connection with Mr. Robert Spurr Weston's statement claiming greater efficiency for slow sand filters over mechanical filters in the removal of iron from ground waters, this is not based on any experience that the speaker is familiar with. As a matter of fact there are very few slow sand plants removing iron from ground water

in the United States; in fact, the speaker knows of none outside of New England; while all through New Jersey, where iron occurs in ground waters, there are many mechanical filtration plants, and in the west there are very notable examples, such as Iowa City and Freeport, Illinois, preferring the gravity type, most of the New Jersey plants being of the pressure type. Nearly all of the iron removal mechanical filtration plants operate too at the rate of about 250,000,000 gallons per acre a day and it should be borne in mind that while a slow sand filtration plant may successfully remove iron from ground water at the high rate of 10,000,000 gallons per acre, it is equally true that mechanical filter plants in many cases are removing iron satisfactorily at a rate of 250,000,000 gallons per acre.

The speaker would like to say this, too, that in the development of mechanical filtration he believes that the pressure filter is becoming more and more effective. The pressure filter is probably the most abused form of filter that we have; and yet the work it has done, to those who have closely watched its performance, is very remarkable indeed. When the speaker says that it will come into its own, he does so because in these days, when chemicals are used without prejudice, sterilization is being depended upon for purification in the sanitary sense and the filter becomes more and more a clarifying and decoloring proposition, and because of the fact that the larger number of water supplies in the United States are clear waters, that is, waters not carrying turbidity beyond 150 or 200 p.p.m., one can realize that a device so economical and so readily installed as the pressure filter must attract a great deal of attention in this connection when absolute sterilizations can be had after decolorization and clarification by filtration.

In the discussion of Mr. Johnson's paper at the New York Section, a very curious theory, that is curious to the speaker, was advanced, to the effect that, while filtration either slow sand or mechanical had reduced the typhoid rate to an average of above 75 per cent in cities employing it, where mechanical filtration had been installed no corresponding decrease in the total death rate occurred, whereas in the case of slow sand filters there was a notable decrease in both the total and the typhoid death rate. The speaker must confess that he did not feel in a position to contradict this at the time, although as a mathematical proposition it did not exactly ring right to him; but he has taken the trouble to have compiled a set of statistics that, in connection with Mr. Johnson's paper, will prove

very interesting, and bear out the more widely distributed data submitted by him. In general all these figures show that there is not what you might call a corresponding decrease with either slow sand or mechanical filtration as to the total death rate when you consider the very great decrease of the typhoid death rate. As a matter of fact, in the Rhode Island communities where statistics have been available disclosing both slow sand and mechanical results we get a total death rate reduction that averages about 10 per cent; while the total average typhoid death rate runs around 46 per cent. It should be remembered that Rhode Island is a great manufacturing center, employing transient and foreign labor. Herewith are submitted these Rhode Island statistics for your inspection:

East Providence mechanical filters

YEAR	POPULATION	TOTAL DEATHS	RATE PER 1,000	TYPHOID DEATHS	TYPHOID RATE PER 100,000
1891	8,778	144	16.4	3	34
1892	9,170	159	17.3	3	33
1893	9,386	150	16.0	2	21
1894	9,773	171	17.4	3	31
1895	10,170	160	15.7	7	69
1896	10,572	156	14.7	3	28
1897	10,987	163	14.8	2	18
1898	11,432	123	10.8	0	0
1899	11,813	141	12.0	2	17
1900	12,138	211	17.4	6	50
1901	12,533	162	13.0	1	8
1902	12,851	171	13.4	4	31
1903	13,791	229	16.8	4	30
1904	13,328	204	15.3	0	0
1905	13,750	187	13.6	2	15
1906	14,072	221	15.7	2	14
1907	14,395	227	15.8	2	14
1908	14,717	213	14.5	2	14
1909	15,396	211	13.7	1	6
1910	15,808	233	14.8	0	0
1911	16,220	207	12.8	1	6
1912	16,632	194	11.7	1	6
Average eight years before filtration 1891–1898.....			15.4		29
Average fourteen years after filtration 1899–1912.....			14.3		15
			7 per cent reduction		48 per cent reduction

Comments on above table given to Mr. Milligan, April 27.

Providence (city) slow sand filters

YEAR	POPULATION	TOTAL DEATHS	RATE PER 1,000	TYPHOID DEATHS	TYPHOID RATE PER 100,000	TYPHOID PER CENT OF TOTAL DEATHS
1899	165,666	3,162	19.1	42	25	1.33
1900	175,597	3,678	20.9	39	22	1.05
1901	180,355	3,444	19.1	46	26	1.33
1902	186,294	3,394	18.2	38	20	1.12
1903	191,937	3,895	20.3	39	20	1.00
1904	194,027	3,593	18.5	29	15	0.81
1905	198,635	3,474	17.5	39	20	1.12
1906	203,243	3,816	18.8	40	20	1.05
1907	207,850	4,001	19.2	17	8	0.42
1908	212,458	3,570	16.8	35	16	0.98
1909	219,188	3,535	16.1	28	13	0.79
1910	224,326	3,982	17.7	40	18	1.00
1911	229,464	3,598	15.6	28	12	0.78
1912	234,602	3,722	15.8	25	11	0.67
Average seven years before filtration 1899–1905.....			19.1		21	
Average seven years after filtration 1906–1912.....			17.1		14	
			10 per cent reduction		33⅓ per cent reduction	

Bristol County mechanical filters

YEAR	POPULATION	TOTAL DEATHS	DEATH RATE 1,000	TYPHOID DEATHS	TYPHOID RATE 100,000	TYPHOID PER CENT OF TOTAL DEATHS
1900	13,144	297	22.6	4	31	1.35
1901	13,396	240	17.9	7	52	2.92
1902	13,595	250	18.4	2	15	0.80
1903	13,962	277	19.8	2	14	0.72
1904	14,667	264	18.0	5	34	1.89
1905	15,048	296	17.8	0	0	0
1906	15,429	257	16.7	1	7	0.39
1907	15,809	262	16.6	2	13	0.76
1908	16,190	249	15.4	1	6	0.40
1909	17,091	240	14.0	2	12	0.83
1910	17,602	325	18.5	0	0	0
1911	18,113	303	16.7	1	6	0.33
1912	18,624	296	15.9	2	11	0.67
Average eight years before filtration 1900–1907.....			18.5		21	
Average four years after filtration 1909–1912.....			16.3		7	
			12 per cent reduction		66⅔ per cent reduction	

Newport (city) mechanical filters

YEAR	POPULATION	TOTAL DEATHS	RATE PER 1,000	TYPHOID DEATHS	TYPHOID RATE PER 100,000	TYPHOID PER CENT OF TOTAL DEATHS
1901	22,403	386	17.2	8	36	2.07
1902	22,670	424	18.7	8	35	1.89
1903	23,233	359	15.5	4	17	1.11
1904	24,438	340	13.9	4	16	1.18
1905	25,039	394	15.7	7	28	1.78
1906	25,559	339	13.3	4	16	1.18
1907	26,241	373	14.2	1	4	0.27
1908	26,842	342	12.8	2	8	0.58
1909	26,727	382	14.3	1	4	0.26
1910	27,149	383	14.1	5	18	1.31
1911	27,571	364	13.2	4	14	1.10
1912	27,993	405	14.4	3	11	0.74
Average nine years before filtration 1901–1909.....			15.1		18	
Average two years after filtration 1911–1912.....			13.8		12½	
			9 per cent reduction		31 per cent reduction	

MR. F. A. DALLYN: The last gentleman's remarks regarding vital statistics present a very interesting problem. The speaker stated that he himself had gone into the matter a few months ago in connection with the typhoid death rates in Ontario. Deductions based upon the total deaths are of very little value taken by themselves. The significance of total deaths is badly interfered with by the fact that the infant death rate is included in the total deaths. The infant death rate in cities is usually abnormal, due to the presence of institutions in those centers. The institutional death rate has been simply terrific in past years. Actual investigation in Toronto and Ottawa, two centers which have institutions for infants, showed that the death rate in those cities is abnormal, being about three or four times the rate for the surrounding rural districts; the congestion and the institutions are the primary causes for this excess. The infant death rate in some centers is almost half the total death rate. Possibly the best method of making a comparison between cities would be to exclude the infant death rate under five years, which would leave a rate that is probably sympathic for typhoid, the total deaths and bad water supplies.

MR. PAUL HANSEN: The speaker does not wish to refute Mr. Milligan's statement with reference to pressure filters; but does wish to say that pressure filters should not be adopted except with extreme precautions and in exceptional cases. In the first place, pressure filters are very inaccessible; in the second place, if operated as pressure filters, it is not feasible to use coagulation and sedimentation preliminary to filtration. Therefore it is not easy to get as good results as with the open type of filters.

In the state of Illinois we have one striking instance of how difficult it is to treat water with pressure filters, owing to the fact that it is not possible to secure good reaction with the chemicals and the proper sedimentation preliminary to filtration; if pressure filters are applicable at all they are applicable to waters that are already clear or nearly so, and which require merely slight filtration to give them the proper physical characteristics and then sterilization must be relied upon to take out objectionable bacteria.

MR. CHARLES B. BURDICK: The author states at the conclusion of the paper that the average cost of rapid sand filtration is $5.70 per million gallons, and that for slow sand filtration $7.33 per million gallons. The method for arriving at this cost is by taking the cost per million gallons of these plants and multiplying it by 5 per cent, that is, in computation of the fixed charges, and dividing it by 365, the number of days in the year. This computation of the fixed charges assumes that the plant operates at 100 per cent of its capacity throughout the year. The statistics of the several plants given here show that the various plants average very materially less than 100 per cent. Some of the plants noted, one particularly, have a percentage of operation as small as 40 per cent and somewhere around 85 per cent or 90 per cent is the highest rate, and that only in places where there are probably other sources of water supply than the particular plant mentioned. It is safe to say that throughout the life of a mechanical filtration plant or a slow sand filtration plant it is probable that the rate of delivery will not exceed perhaps two-thirds of the rated capacity day in and day out, under which circumstances it will be necessary to add about 50 per cent to the fixed charges mentioned here, which will result in cost around $10 for slow sand filtration based on these figures of cost of installation, and $6.50 for mechanical filtration.

MR. H. F. DUNHAM: While it is true that every new piece of work must be regarded as a separate affair or problem, the questions of the greatest interest in this discussion cling around those general features which are common to all installations; the element of risk is such a feature. It seems to have been overlooked; it is more apparent in some designs than it is in others, and is more a factor in some classes of construction than in others, but it always persists, and pertains to time intervals as well as to the incidents of construction, and the failure of work after construction.

Let it be assumed a given object or purpose is to be accomplished by certain well defined means, or by one method, in a given interval of time. Then, if the same result can be reached by another method, involving construction expenditures only one-half or one-third as large, this second method is far in excess of the estimated difference in cost under favorable and known conditions; for it may be necessary to carry out the work under conditions that are not favorable and known.

Speaking generally, there is no doubt that a large area of land can be purchased at less cost per acre than a small area, but the large area cannot be covered with brick or concrete structures without involving greater risks. Bonding and insurance companies would recognize that fact. There is evidence to show that no class of filtration work is exempt from accident and failure.

MR. H. C. HODGKINS: If the speaker has read this paper correctly the charge in one instance for interest and depreciation was 5 per cent; in Mr. Fuller's paper he gave the rate for interest and depreciation at 4.75 per cent. This calls to mind an article prepared by a member of this Association in which he undertook to work out a rate charge, and in which he figures out depreciation and interest charges at an average of 8 per cent; that paper is a matter of record.

Now it has impressed the speaker that, if he was putting some money into a filter plant of his own, he would want to see more than 5 per cent for interest and depreciation, the proper rate ought to be higher than that in estimating the cost of any engineering structure.

MR. J. N. CHESTER: This discussion reminds the speaker of the old saying that the first story-teller "don't stand no show." If it comes to reciting costs, of course any cost may be questioned. The first filter with which the speaker was connected was a slow sand

filter, the third built in the United States; built and in operation along the New Haven Railroad thirteen miles from the Grand Central Station, New York City. It was built twenty years ago. The speaker was not called in to say that it should be built; but learned afterwards that the company, not the present owners, wanted to issue some bonds and they thought it would be a good thing to have some construction work in progress, so they commissioned him to build a filter plant. They did not ask for an estimate at all, but gave directions to build it. There were no plans made, other than a sketch on the back of an envelope. We succeeded in building a plant covering 1.4 acres for $22,000. We created that filter by damming off part of a reservoir. We took no precautions to keep out the ground water, of which we had considerable. We obtained our sand, which was excellent, from a bank adjacent to the site; our stone and our gravel came from the same source. We shipped in little. We used wooden boxes for under drains; we had no clear water basin other than a small suction well; and no sedimentation basin. You will allow that this plant should filter at least 4,000,000 or 5,000,000 gallons per day, so here is a slow sand unit with which you can compare.

We frequently get in our office a commission to design a small filter plant, and generally where a small filter plant is wanted there is a minimum amount of money available. It is not exceptional to build a half million gallon unit, or anywhere from that to a 1,000,000 gallon unit, at from $5,000 to $10,000. But how do we do it? Sometimes we put up two small wooden tubs that constitute the filters. We will probably put in wrought iron manifold systems. We will wash with direct pressure from high pressure mains. For sedimentation we may put in wooden tanks. For coagulant tanks we may set up a couple of barrels, and we will improvise the orifice boxes. We will use hand valves and wrought iron pipe throughout. When we get through they will have a filter plant that will probably filter as good as anybody's, but it will depreciate very rapidly and it will incur a high cost of operation. However, the state board of health has ordered them to filter. They have only so much money and they say, "Won't you please, Sir, design us a plant that we can put in with that amount?" But it is not fair to compare those prices with prices of up-to-date plants. When that Mount Vernon filter plant was built we paid $1 for the day laborer. We could stand over those men with a whip and crack it vigorously. We got

three days' work measured by the day's work that a man does today. It was in the worst part of the panic of 1893 and 1894, and we of course availed ourselves of the low price of labor, and paid nothing for the material, so it only cost the labor.

In earlier years, in designing and building filter plants we did not design such a plant as is ordinarily built today, but we put in a number of tubs or units and built a house over them. There are a great many of those filter plants over the country today.

Today when you start to build a 10,000,000 gallon or 20,000,000 gallon filter, you put a whole lot of money into what we call a "head house" or "coagulation house," or the administration building, or whatever you may please to call it. You will spend $2,000 or $4,000 or even $6,000 per million gallons for that element of the filter. You can design them for as little or as much as you or your client demands. The more you pay for, the more you have, and the less you pay for, the less you have. You take a half million unit filter plant, with hand-operated valves, 6 inches in size, and then you increase the size of the unit to 1,000,000 gallons and begin to think about hydraulic valves, and you will have to add several hundred dollars per million gallons for that single thought. It is easy to criticise someone's prices or someone's statement without analyzing.

Pressure filters *may* get a good hold again, but the speaker does not see just how they can be quite as acceptable as open filters; and his reasons for thinking so are something on the same line as Mr. Hansen's. You can put water into a sedimentation coagulation basin after first coagulating it, then pick it up with pumps and send it through the filters; but in so doing you handle your floc pretty roughly. The speaker does not say that pressure filters will not do good work, for the pressure type of filters at Little Rock and Chattanooga are still doing good work, but working under gravity pressure. They are not as desirable as open filters because we can not see what is going on. When you build such filters horizontal you get a curve on them that makes trouble. Mr. Weston can testify to that for he tested the first pressure filters that the speaker ever had to do with, and we found that there was clay in the segments of the filters that projected out over the strainers. Let the speaker say that he has found that same trouble in every horizontal filter with which he has had to do.

Finally regarding Mr. Hawley's comments and the results that

he shows, let the speaker caution you who are expecting such results that the credit is not due the filter company that built the plant or the engineers that did the designing, but the very careful manner in which it is operated.

Mr. GEORGE A. JOHNSON (*author's closure*): The author has read Mr. Gregory's discussion of his paper with much interest.

It is undoubtedly true, as Mr. Gregory states, that at Albany, Philadelphia, Pittsburgh, Cincinnati and Columbus the sites selected for the filtration plants, which were later built, were well advised. Nevertheless, the author still contends that there is always bound to be a wide difference in the cost of land for slow sand and rapid sand filter plants, the same roughly approximating a ratio of 20 to 1, as stated.

In citing his exceptions to the author's viewpoint, Mr. Gregory bases his conclusions that the above ratio is too high mainly upon the condition which sometimes obtains, wherein a large tract of land can be bought for a sum not much greater than that demanded for a small portion of the same tract. In such a case it may be, and often is, good business policy to acquire the larger tract, even though only a small part of it actually would be utilized for the filter plant. The balance would have a value that should not stand as a charge against the cost of land for the filter plant, and it might profitably be sold at some future time if desired. Does not, therefore, the relative cost of land for filter plants of the two types reduce itself to a proposition of actual area utilized? Giving to the slow sand filter credit for a normal rate of filtration of 5,000,000 gallons per acre daily, and to the rapid sand filter a normal rate of 120,000,000 gallons per acre daily, in a 20,000,000 gallon plant of each type, for the filters alone, 4 acres of land would be required for actual slow sand filter area as against 0.17 acre for actual rapid sand filter area. This is in the ratio of 24 to 1, and the additional ground required for basins, buildings and other parts of plants of both types will not reduce this ratio materially. Much larger preliminary settling basins are called for in slow sand filter installations than in plants of the rapid sand type. A reserve filtering area of some 10 per cent is demanded in plants of the slow sand type but not in plants of the rapid sand type; and numerous other items certainly will tend to hold close up to the mark the required land ratio of 20 to 1, as stated by the author.

With reference to Mr. Gregory's comments on costs of construction of slow and rapid sand filter plants, the author agrees with him that it is exceedingly difficult to satisfactorily compare such costs. Local conditions always control in a large measure, referring to the character of the raw water, topographical conditions, availability and cost of building materials, cost of labor, etc. As to reservoir capacities, they, too, control, but it is not to be denied that many rapid sand filter plants have been provided with needlessly large settling basins, whereas this is not true in the case of any slow sand filter plant of which the author has knowledge. If it were, then such improvements along the line of preparatory treatment as have been made at Albany, Washington, Pittsburgh and elsewhere, and such as are contemplated at Philadelphia, would have been unnecessary.

With reference to the cost of the Little Falls, New Jersey, plant, Mr. Gregory must know that the desire to avoid double pumping, coupled with the very small area of suitable land available and the necessity for building the plant on high ground above flood water levels, made imperative the strikingly deep basins found at that plant. These factors made the cost of this plant as high as it was. The coagulating basin provided may have been too small, judged by present practice, but the plant was built 12 years ago, before such things were as well understood as they are today. Nevertheless the cost of operation and results obtained at the Little Falls plant in the dozen years it has been in successful operation compare most favorably with those at any other filter plant of its type in the world. Owing to the existence of several large reservoirs on the distribution system a large clear-water basin was not called for. The one provided has proved to be of ample size.

The Columbus plant, which Mr. Gregory cites, is a water softening as well as a water filtering plant, therefore large settling capacity was called for. Lacking distributing reservoirs it was necessary to provide large filtered water reservoir capacity. It therefore is manifestly improper for Mr. Gregory to compare reservoir capacities at Columbus and Little Falls, as the controlling conditions at the two places are entirely different.

With reference to Mr. Gregory's comments on the Albany, New York, slow sand filter plant, it is true that its present daily capacity, due to the addition of preliminary filters to the original layout, and certain changes in methods of operation, may be as high as 28,000,000 gallons instead of 20,000,000 gallons, as stated by the author. But

the author wonders whether Mr. Gregory considers this plant in the light of a true slow sand filter, and if he has given thought to the possibility that, for a large part if not all of the time, the operation of the final slow sand filters might possibly be dispensed with, without affecting the efficiency of the plant as a whole. This being the case, perhaps it might be considered that the Albany plant is, to all intents and purposes, a rapid sand filter plant, in which event the cost of construction of such parts as are actually necessary would be far below the figure given by Mr. Gregory, namely, $14,300 per million gallons daily capacity.

The author agrees with Mr. Gregory that the Philadelphia slow sand filter plants were expensive.

The cost of the Toronto slow sand filter plant, mentioned by Mr. Gregory, was not unknown to the author; as extensions to the filtration system are being made along radically different lines, he did not consider it necessary to mention this plant. Furthermore, he was restricting his paper to United States practices.

The author would not change the weighted average cost of slow sand filters given in his paper in consequence of the arguments cited by Mr. Gregory, for the above reasons.

As regards the cost of the Columbus rapid sand filter plant, it is to be recalled that this is a water softening as well as filtration plant. The total cost of the filtration and softening works is given by Mr. Gregory as $17,750 per million gallons daily capacity (Trans. Am. Soc. C. E., vol. lxvii, 1910). The items which should be omitted from this figure, if the plant is to be considered as a water filtration plant, eliminating the softening feature, are those for the lime saturator house ($1080), and mixing tanks ($1470). On account of the necessity for providing large settling tanks wherein the softening reactions are completed an allowance should be made there. Instead of twelve hours' capacity three hours would be ample for filtration alone, hence from the item of $168,770 for the full twelve hours' settling capacity, or $5630 per million gallons daily filtering capacity, this item should be reduced to at least $2000, a reduction of $3630 per million gallons. The head house, while suitable in all ways for a combined water softening and filtration plant, is too large and contains apparatus of no use in ordinary water filtration. The same is true of the storage house which was made necessarily large to accommodate the huge reserve supply of softening chemicals.

From all the above it is clear to the author that his cost of $13,000 per million gallons for building the Columbus filtration works proper is entirely reasonable.

Much the same argument against Mr. Gregory's viewpoint as to the cost of rapid sand filtration works, where the softening accessories are eliminated, may be made in the case of the Grand Rapids plant, referred to by him.

As to the proposed rapid sand filter plant for New York City, mentioned by Mr. Gregory, the author, like Mr. Gregory, also served as one of a commission of consulting engineers on this project, and is therefore more or less familiar with the matter; and he knows that the cost per million gallons daily capacity, were it not for the unusually large clear water basin provided for this 320,000,000 gallon daily plant, namely, 365,000,000 gallons, would more nearly approach $12,500 per million gallons than the figure cited by Mr. Gregory. At that the low bid for the entire plant, including the large clear water reservoir, was $5,139,015, or $16,060 per million gallons daily capacity.

As to the Cincinnati rapid sand filter plant, the author differs from Mr. Gregory in the opinion that the large storage reservoirs, providing at the present time some six days' storage, should be considered a part of the filtration plant. He does not consider any such preliminary sedimentation of the raw Ohio River water necessary, nor would he provide it. In his recent consideration of rapid sand filtration for the city of Wheeling, West Virginia, he made no such provision, deeming it an unnecessary and uncalled for expense.

The New Orleans rapid sand filter plant, cited by Mr. Gregory, was an unusually expensive one to build, owing to bad foundation conditions, a point not mentioned by Mr. Gregory when stating the cost of this plant as $30,200 per million gallons daily capacity.

The author does not feel that Mr. Gregory's contentions are sound, or that he has made out a clear case that the author's cost for rapid sand filters is too low, and for slow sand filters too high. The author holds no brief for rapid sand filters, any more than Mr. Gregory does for slow sand filters, and in his paper merely cited a few examples which he had no idea would be taken as criteria of the relative cost of the two types of plants. In his closing remarks the author was particular to state:

Questions of cost alone should never govern the manner of dealing with problems affecting public health and comfort. It so happens, however, that slow sand and rapid sand filtration costs about the same, with the advantage of lower cost usually in favor of the rapid sand process. A human life is customarily valued at $5000 and a difference of even $15 per million gallons for water filtration, one way or the other, amounts in a year's time to about the value of one human life.

Mr. Maignen's remarks relative to the actual inefficiency of preliminary filters are interesting. Such filters had their origin in the desire to relieve the final slow sand filters of their occasional unbearable load of suspended matter. But, as Mr. Maignen says, they take out the coarse particles and allow the finer particles to pass onto the slow sand filter into which they penetrate to considerable depth, indeed sometimes passing entirely through them, as at Torresdale. Therefore, to make preliminary filters efficient it is necessary to use coagulants, and when the preliminary filters are properly built and operated and coagulants are used, of what earthly use are the final slow sand filters, particularly when the filtered effluent is sterilized?

Mr. Hawley's reference to the Pittsburgh filter plant may, perhaps, create an erroneous impression with respect to the exceedingly good work which is being done by that plant. Nevertheless the author is in thorough accord with Mr. Hawley in the belief that if the purification of the Allegheny River at Pittsburgh were to be considered as a new problem today, rapid sand filters would be adopted. The original plant, by virtue of highly skilled supervision, has done and is now doing excellent work; but as good, if not even better, work could be done by a regulation rapid sand filter plant, and the operation of such a plant would be far less difficult.

Mr. Hawley's description of the results obtained at the Wilkinsburg, Pennsylvania, plant are most interesting and instructive.

Regarding Mr. Chester's remarks on costs of construction, the author realizes, of course, that local conditions and local ideas largely control such matters. He knows that at some places the muddy character of the raw water makes it expedient to use larger settling basins than would be demanded at other places where the turbidity of the raw water is lower. Nevertheless he believes this idea has been carried much too far in some cases, as very muddy waters usually contain a large percentage of heavy sediment which will settle out in a very short time.

If it is desired by a given community to minimize the cost of the filtration works, then it assuredly can be done by cutting out what Mr. Trautwine calls "frills." Conversely, if civic pride impels another community to "go the limit" on such things, and make the works "a beauty and a joy forever," then the cost of the works will increase accordingly. In other words, it is perfectly possible to construct in a suitable manner, well appearing, fully equipped filter plants of modern design for the figures given in the author's paper, and do so without in the slightest degree impairing the stability or efficiency of the plant.

The author heartily agrees with Mr. Leisen that the whole subject covered by the author's paper should be thoroughly discussed without passion or prejudice, and has been pleased to note that for the most part the various discussions submitted have been along that line.

The author cannot subscribe to Mr. Weston's conclusion that for iron removal the slow sand filter is cheaper and better than the rapid sand filter. He wishes Mr. Weston had cited a few examples and experiences to support his statement.

Mr. Armstrong's statement that the cost of the Baltimore rapid sand filter plant, now building, will be less than $12,000 per million gallons, comes from a source, the reliability of which must be recognized. It merely goes to show that whether or not some rapid sand filter plants have cost more than $12,500 per million gallons capacity, there are many which have been and are being built for even less.

Mr. Trautwine's historical sketch of the development of the filtration problem in Philadelphia is most interesting. It still remains a good deal of a mystery to many others besides Mr. Trautwine why the slow sand process was finally adopted at Philadelphia.

Mr. Milligan's discussion of construction cost factors, and the relative applicability of slow and rapid filters for iron removal is along the line of the author's own ideas.

One point brought up by Mr. Milligan the author wishes to comment on at length. This refers to the statement, or suggestion, made on March 10, when the author addressed the New York Section of this Association on the subject matter of this paper. The statement referred to was in effect that whereas with both types of filters there followed about the same reduction in the typhoid fever death rate among the consumers, the total death rate was materially

reduced among the users of slow sand filtered water while among the users of rapid sand filtered water such reductions were not noted; in fact in some instances sharp increases in the total death rate had followed the introduction of rapid sand filters.

This statement created considerable of a sensation, and accordingly the author wrote to the health authorities in several cities for data bearing on the point in question. In the following table (p. 516) the data received from eight slow sand and seven rapid sand filter cities are presented in detail.

So far as such statistics may be relied upon, and they are all that we have from which to judge such things, it is seen that, speaking broadly, there is nothing to choose between the two systems so far as concerns the relative reduction in the total death rate and the typhoid fever death rate as the result of filtration of the water supply. This is made somewhat clearer in the following table wherein the figures given in the foregoing table are condensed. Mr. Milligan's figures tell the same story.

Total death rate and typhoid fever death rate in cities before and after filtration

CLASSIFICATION		KIND OF FILTRATION	
		Slow Sand	Rapid Sand
Total death rate per 100,000	Before filtration	1863	1883
	After filtration	1688	1778
Typhoid death rate per 100,000	Before filtration	70	64
	After filtration	27	22
Per cent reduction after filtration	Total	9	6
	Typhoid	61	66

It is perfectly clear why this should be and is so. The typhoid fever death rate is reduced equally by both systems, but variations in the total death rate, which is many times the typhoid fever death rate, are caused by outbreaks of specific diseases other than typhoid fever and due to other than water-borne diseases. Infantile diseases, accountable for a higher infantile death rate some years than others, probably are responsible for the majority of sharp variations from the normal in the total death rate. Improved general sanitary conditions will always be followed by a decreased total death rate. Campaigns for purer milk supplies, fly elimination, improved hospital facilities and so on, will always effect a reduction in the total death rate.

Total death rates and typhoid fever death rates before and after filtration of the public water supply
(Compiled from data kindly furnished by the health officials in the various cities named)

KIND OF FILTRATION			SLOW SAND								RAPID SAND						
City			Pittsburgh, Pa.	Washington, D.C.	Albany, N.Y.	Philadelphia, Pa.	Springfield, Mass.	Indianapolis, Ind.	Wilmington, Del.	Lawrence, Mass.	Binghamton, N.Y.	Youngstown, O.	Burlington, Vt.	Cincinnati, O.	Watertown, N.Y.	New Orleans, La.	Columbus, O.
Total death rate per 100,000 population	Years Before Filtration	5	2110	2130	2160	1770	1430	1340		2192	1530	1340	2260	1830	1980	2220	1610
		4	1970	2010	2070	1889	1540	1230	1642	2566	1740	1480	2160	2060	1740	2350	1490
		3	1950	2020	2250	1856	1490	1180	1556	2652	1840	1530	2530	1890	1510	2140	1530
		2	1920	2080	2500	1740	1460	1240	1464	2446	1980	1605	2520	2020	1690	2340	1550
		1	1830	2040	2630	1886	1370	1290	1464	2614	1890	1725	2360	1810	1900	2220	1520
	Years After Filtration	1	1730	2030	1950	1859	1570	1210	1751	1897	1810	1685	2180	1800	1710	2020	1400
		2	1580	2010	1880	1744	1470	1200	1625	2032	1490	1500	2310	1630	1930	2140	1540
		3	1790	1980	1710	1623	1430	1230	1557	2030	1880	1593	2060	1740	2260	2040	1430
		4	1490	1910	1910	1729	1630	1100	1433	2058	1900	1446	2120	1690	1320	2020	1440
		5	1590	1960	1930	1650	1550	1110		1974	1840	1541	1930	1730	1570	1990	1530
Typhoid fever death rate per 100,000 population	Years Before Filtration	5	134	60	134	44	18	45		113	42	87	6	43	65	36	135
		4	142	78	72	69	24	34	34	126	75	124	11	81	65	32	73
		3	99	48	88	53	14	42	30	134	52	118	22	45	76	30	34
		2	130	47	94	48	25	49	21	119	58	116	11	68	90	55	36
		1	125	47	74	72	20	73	24	105	70	80	21	44	214	33	104
	Years After Filtration	1	49	52	39	59	23	35	32	49	35	52	10	18	26	29	17
		2	25	36	22	35	20	33	24	34	14	48	10	13	54	32	16
		3	28	39	29	21	9	29	24	26	17	31	5	6	40	31	14
		4	26	35	20	17	11	27	15	25	19	38	0	12	42	14	20
		5	13	24	20	14	8	20		24	17	30	5	8	33	16	19
Average total death rate	Before filtration		1956	2056	2320	1829	1460	1256	1531	2494	1796	1536	2366	1922	1764	2254	1540
	After filtration		1636	1980	1880	1721	1530	1170	1591	1998	1784	1553	2120	1718	1758	2042	1470
Average typhoid death rate	Before filtration		126	56	92	57	20	49	27	119	59	105	14	56	102	37	76
	After filtration		28	37	26	29	14	29	24	32	20	40	6	11	39	22	17
Per cent reduction following filtration	Total death rate		12	4	18	6	*5	7	*4	20	1	*1	10	11	0	9	4
	Typhoid death rate		78	34	72	50	30	41	11	73	66	62	57	80	62	40	78

* Increase

Mr. Dallyn's comments relative to the necessity of eliminating the infant death rate in order to obtain something like a definite value from vital statistics is a point well taken.

As to Mr. Hansen's comments on pressure filters, the author is of the opinion that the main reason why they are not in such favor as gravity filters is that in the past they have been looked upon as automatic and requiring but very little attention. They are not so capable of control as are gravity filters, and consequently are more liable to go wrong. But if the effluent is sterilized they certainly have a field of usefulness which is by no means small. In other words water sterilization, as developed in the past five or six years, will do as much toward furthering the field of usefulness of pressure filters as for any other type of filter.

Mr. Burdick's contention relative to the actual cost of filtration, based on the ground that most filtration plants operate at only some two-thirds their full capacity throughout the year, has considerable merit. He believes on this account that the fixed charges mentioned by the author should in some cases be increased by about 50 per cent. Now in a measure this is true. Of course it cuts both ways, perhaps, other things being equal, a little deeper with slow sand filters on account of the greater reserve areas required. But it has always been the custom to design filtration plants of capacities considerably in excess of immediate needs in order to anticipate emergencies. A filter plant must be prepared to handle peak loads, for water consumptions vary greatly with the seasons, and increased water consumption frequently is to be expected following the substitution of pure filtered water for the former impure and unsightly supply. The average daily consumption throughout a given year cannot be taken as governing the size of filter plant to be built.

To Mr. Dunham's comments regarding the element of risk entering into questions of cost of construction the author would state his entire coincidence.

In some measure Mr. Hodgkins is right on the proposition of 5 per cent interest charges; but he includes depreciation. The figure used by the author was for interest on the investment, solely, but feeling that the comparison between the two types of filters was not thereby affected, and since he was not striving at exceptional accuracy as to costs, as the closing paragraph of his reply to Mr. Gregory's discussion will show, perhaps he was not any too specific. Even in these hard times, though, there is still considerable money,

* Increase

on relatively large investments, to be had at even less than 5 per cent.

The author notes Mr. Whipple's statement that the rapid sand process predominates at the present time, and in view of what Mr. West has to say about the proposed changes at the Torresdale plant, and what is being done at Albany and elsewhere, it seems very clear to the author that the degree of predominance of the rapid sand idea is much greater than appears on paper at this date.

It is very true that the use of oxygenated compounds of lime and soda has materially broadened the field of filtration in general, and the author knows that this applies with quite as great force to slow sand filter plants as to rapid sand filter plants, probably more in the case of the former, which are well known to show greater evidences of hygienic failure in the colder months of the year.

Mr. Whipple's strictures regarding the cost statistics given by the author are graciously noted. These figures were merely shown in a suggestive way, and were not intended to be taken as criteria. Nevertheless the author would appreciate having Mr. Whipple exercise his well-known statistical ability, and give to the profession the complete data on comparative costs he seems to think necessary. The author trusts that when Mr. Whipple attempts this trifling task he will detail all his figures and not lay himself open to the criticism he himself directs at the author.

Mr. Whipple criticises the author's statement that slow sand filters are out of their element when chemicals are used in connection with their operation, and states that by studying the cost and results of operation at Springfield, Massachusetts, and Washington, D. C., one may learn that chemicals may be economically applied with great benefit. Looking at the matter broadly, however, the author believes his own position to be prefectly correct. Furthermore, he cannot refrain from quoting in this connection the sound and logical conclusion of Mr. Allen Hazen, in his book, *Clean Water and How to Get it* (1914, pp. 95–6).

> Sand filters are used in connection with various preliminary treatments, but, generally speaking, they are adapted to treating only such waters as are capable of being purified in that way without any preliminary treatments, or with only rough and inexpensive treatments. If the water ordinarily requires coagulation, then, as a rule, it will be better to make the coagulation thorough and use mechanical filters for the final treatment.

As to the hygienic efficiency of filtration, the author is inclined to believe with Mr. Whipple that it actually is nearer 100 per cent than 70 per cent, as stated by the author, the residual typhoid in cities having well built and well operated water filtration works coming from other sources than the public water supply. He is gratified to note that Mr. Whipple agrees with him in that water filtration is capable of preventing the spread of water-borne diseases, and that from a hygienic standpoint there is little to choose between the slow sand and rapid sand filtration processes.

The author differs from Mr. Whipple on the proposition that poor operation of rapid sand filters is likely to do more damage than poor operation of slow sand filters. Neither type of filter will run itself, and if anything happens to a slow sand filter it is out of commission for days, while with a rapid sand filter the error, if such occurs, can be, and usually is, remedied almost at once. He agrees with Mr. Whipple, however, that it is far more difficult to secure in small plants the high degree of expert supervision ordinarily true in large plants. This is not a fault or weakness of filtration processes but due entirely to local politics and false ideas of economy.

As to Mr. Whipple's closing remarks, the author has never denied that slow sand filtration may have a field of usefulness, but it certainly is a small one as shown by facts published by others than the author. Mr. Whipple is clearly mistaken in his assertion that most engineers have long since ceased to talk about the relative merits of slow sand and rapid sand filtration, for it is a fact that the majority of engineers have foresworn such undivided allegiance as they may formerly have held to the slow sand process, and are now supporting the rapid sand process. The developments of the last ten years alone prove that.

The author agrees with Mr. Caird that something might have been said about the status of filtration practices abroad. He thought, however, that one bite at a time, reasonably well Fletcherized, was about enough, and accordingly restricted his efforts to the United States. He would say, however, that in western Europe, where the waters are relatively clear, the slow sand filter still predominates, although there are notable examples of rapid sand filters in that region, as at Trieste, Austria; Posen, Germany; and Helsingfors, Finland. In the Far East, India and Egypt, where the raw waters usually are muddier and more nearly to be compared with our cen-

tral western waters, the rapid sand process has made great strides in recent years; the more notable of the recent installations of plants of that type being those at Cairo, Egypt; Bangalore, Dacca and Hubli, India; Bankok, Siam; Taihoku, Formosa; Inkao, Manchuria; and Kyoto, Japan. The last named plant treats the waters of Lake Biwa, which are rarely very muddy, as we understand the term.

Altogether there are rapid sand filter plants scattered throughout Canada, Mexico, Colombia, Australia, England, Scotland, Finland, Holland, Roumania, Austria, Russia, Egypt, India, Siam, China, Japan and elsewhere, having at the present time a daily filtering capacity of about 150,000,000 gallons.

Mr. Caird's comparison of results obtained at the Washington, D. C., slow sand filter plant, and at the Elmira, New York, rapid sand filter plant, are interesting and instructive.

With reference to Mr. Caird's conclusion that strainer heads are to be preferred to the newer form of underdrains where wire or perforated plate screens are placed over concrete channels containing gravel, the author was interested in noting, during a recent visit to the Cincinnati, Ohio, plant, that as fast as these screens fail at that plant they are being dispensed with entirely, having proved of no advantage.

Mr. Ellms furnishes vital statistics from Cincinnati which further demonstrate the untenability of the idea that while with slow sand filtration the total as well as the typhoid death rate is markedly diminished, with rapid sand filtration such reductions in the total death rate are not noted. His data are convincing, and it is thought that by taking these figures, together with those appearing in Mr. Milligan's discussion, and the author's contribution in connection with the same, this perfectly weird assumption (and it is nothing more) has been shown up in its true light.

Mr. Fuller's well-balanced, fair and logical statements are a source of much gratification to the author who finds no occasion to comment upon them for the reason that his own thoughts are in entire accord with the views expressed by Mr. Fuller.

Mr. Buerger furnishes some valuable figures on the cost of construction of slow sand and rapid sand filter plants, but the author will not comment upon them specifically, merely taking occasion to state that as many more examples could be given where the costs would be all the other way. As an example, take the Trenton,

New Jersey, rapid sand filter plant, which is now nearing completion. This plant has a daily capacity of 30,000,000 gallons, and represents, to the author's way of thinking, a very good example of a thoroughly well-equipped, modern, compact water filtration plant, devoid of unnecessary embellishments, but in all ways architecturally presentable. This plant, omitting the cost of the low-lift pumping equipment, but including everything else, will cost $12,000 per million gallons capacity.

Prompted by Mr. Buerger the author finds that he did inadvertently include a pumping station charge of $1.24 for the cost of operation of the Washington, D. C., filtration plant. This reduces the weighted average given by the author as the cost of operation of the seven slow sand filters by $0.15 per million gallons.

Mr. Buerger's remarks regarding improvements in the design of preliminary filters are interesting, but unlike Mr. Buerger the author does not feel that there will be any preliminary filters in 1922.

Mr. West's discussion, to the author's way of thinking, is of much value for the reason that the views of one who has under his immediate charge the largest filter plant in America are views which safely may be taken with very little, if any, salting.

His statement that when the Torresdale plant has been altered so that coagulants may be used in conjunction with the present preliminary rapid sand filters it will be possible to by-pass the final slow sand filters for nearly 80 per cent of the time is one which may surprise some, but which is no surprise to the author, who worked on the Philadelphia water problem over a dozen years ago, and realized it then.

Mr. West calls attention to the fact that the author made no particular reference in his paper to the use of sterilizing agents in connection with filtration. This is true, but in a former paper, written for the United States Government (Water Supply Paper No. 315,1913, pp. 71–2) the author stated:

> Where waters are unsatisfactory in physical appearance and are also polluted and require filtration, the combined use of filters and the hypochlorite process is called for. As an adjunct to filtration processes it (sterilization) has a distinct field of applicability, for at a moderate cost it insures a water above suspicion. Furthermore, there is brought about a considerable decrease in the first cost of the filtration plant. This is made possible by the use of higher rates of filtration, and the required filter area may therefore be reduced. It also effects a substantial economy in the cost of operation.

Mr. West's comments relative to the shortening of runs on slow sand filters, due to microscopic growths, are interesting. In an address delivered at the Milwaukee convention of the American Public Health Association, in 1910, the author cited as one of the advantages of the hypochlorite process, the fact that it brings about reduced clogging of the filter beds with a consequent lengthening of the runs between cleanings, due to the destruction of various forms of algae.

In closing it appears that a statement is required from the author in reply to certain insinuations which appear here and there in the various discussions of his paper, indicating that it seems to be the idea of some that he holds a brief for the rapid sand filter process.

So far as the comments contained in his paper may be so interpreted, and because of his thorough belief in the entire applicability of the rapid sand process to any and all water purification problems, he certainly has spoken in favor of that process in no uncertain terms, and in that light perhaps may be considered as holding a brief for it, but wishes to be understood as being without the slightest prejudice. The author prepared this paper for the Association because of an earnest desire to set forth a few plain facts which up to now have been given but scant, fragmentary and scattering publicity. He realized in the beginning that the truth might be distasteful to some; that he certainly was laying himself open to criticism for seeming bias, and even might be accused of perverting the facts to the advantage of the process he considered superior. Nevertheless it has always been his habit to express his beliefs in plain and unvarnished fashion, and back them up with actual data. He thinks he has done so in this case; and if unconsciously he has prepared a brief for rapid sand filters merely because of a desire to set forth the truth as he sees it, he cannot see that there is any help for it now and is prepared to accept the consequences, whatever they may be.

Finally, and at the risk of a paradox, to the author's mind the most interesting feature of a paper of this kind is the opposition it develops. He trusts he has answered in an adequate manner such dissenting comments as appear in the discussion, and desires to express his full appreciation to those who participated in the discussion, for many new thoughts have been brought out in a material fashion which add to whatever value the paper may possess.

DISCUSSION

INVESTIGATION INTO THE ADVISABILITY OF SUBSTITUTING AGAR FOR GELATINE AS A MEDIUM FOR THE DETERMINATION OF BACTERIAL COUNTS IN WATER ANALYSIS

By Mr. W. U. C. Baton

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, page, 11, and presented at the Philadelphia Convention of the Association, May, 1914.

Mr. Francis D. West (*by letter*): Before attempting to discuss this question the writer wishes to quote the following from the Report of Committee on Water Supplies, American Public Health Association (*American Journal of Public Health*, December, 1913.)

> There is considerable evidence, too, to indicate that this treatment (with chloride of lime) as applied in the United States does not actually destroy all of the bacteria, but simply stuns or drugs them for a time, or in other words, has a toxic effect which prevents them, for the time being, from developing on ordinary culture media.

This has been the writer's own experience with *B. coli*. He makes tests of 1 and 10 cc. and thinks that a water to be perfectly safe should be consistently free from *B. coli* in 1 cc. and practically free in 10 cc.

MEDIA

There are four commonly used, litmus lactose agar plates, lactose bile, glucose broth (Smith) and liver broth.

For unfiltered waters the writer uses litmus lactose agar plates, getting an approximate number of *B. coli* present. They are always present in unfiltered Delaware River water.

For filtered waters the litmus lactose agar plate is too inhibitory; an enrichment is needed. Lactose bile is the one most commonly used at present. It is to be preferred over glucose for waters of questionable origin, but does have an inhibitive action. American Public Health Association Report, 1912, p. 88 says:

After numerous experiments it has been found that lactose bile medium is slightly inhibitive to *B. coli* especially in attenuated form, so that any positive tests with this medium indicate fresh or recent contamination.

Glucose will give a higher per cent of positive tests with filtered and especially with disinfected water. It is claimed for liver broth that it gives a higher number of positive tests than glucose. The writer has been working for several years with bile and glucose and his experience with liver broth is limited. At present he uses glucose entirely.

The question is which should we use?

Lactose will give a series of negative results with a filtered water when glucose will be positive, especially in 10 cc. tests.

If we find that, after the water has reached the city mains and remained in them some hours, positive tests can be obtained, should not the filter operator use the most delicate test possible for *B. coli:* The filter plant superintendent or the chemist does not want to be put in a position of stating "my tests were all negative" when some bacteriologist antagonistic to the management isolates *B. coli* from the city supply some miles from the filters. It looks in that case like a question of veracity or ability on the part of the chemist. What we need is the most delicate test possible for *B. coli* and try not so much for good records as for true records and make the true records good ones. The writer would like to have the Association bring this subject up and discuss it, as he thinks it very important to both the operator and consumer. We have passed the stage when any water is a good water; what we want is the best and it is our duty to give it.

The writer was one of the chemists who in reply to Mr. Whipple's letter protested against the substitution of agar for gelatine. He, like Mr. Baton, has not changed his opinion on the subject. It is better to make the tests on both media when possible, but if only one is to be used then keep to gelatine.

The writer's experience with agar counts for filter effluents is that they are inconsistent and that spreading colonies and overgrowths are especially noticeable. For lake waters and ponds where soil washing is practically nil, agar will probably be superior; or in cases in which the sample must be stored for a time before testing, the count on gelatine is liable to develop rapidly, while the agar count will remain lower, although the agar count will also change rapidly.

The following table shows the effect of storing at room temperature (70° F.) water that had been filtered and water that had been filtered and disinfected.

TIME	FILTERED		DISINFECTED	
	Gelatine	Agar	Gelatine	Agar
Start	96	21	30	13
1 day	770	320	630	65
2 days	950	430	800	160
3 days	1100	1040	390	290
4 days	1450	1200	495	190
5 days	1430	1300	530	250
7 days	1130	660	270	120
8 days	1000	770	150	250
10 days	700	630	62	92
11 days	910	750	96	136
13 days	600	280	160	24
14 days	240	240	38	88
3 months	10	.....	14	.....

The above data are taken from the tests of the Delaware River water at the Torresdale Filter Plants.

Agar counts corresponding to body temperature bacteria of *B. coli* type are greatly in the minority, the types most commonly found being soil bacteria usually spore bearing. The counts on agar ordinarily increase with the temperature; in the filtered water when the temperature is above 60° F. the number on agar is greater than that on gelatine.

Agar counts in cold weather increase with the turbidity, not so much from increased pollution, as at Torresdale heavy rains usually dilute rather than pollute the water at the intake, but from soil washings. The ratio of gelatine to agar in winter runs as high as 20 to 1; in summer the agar count exceeds the gelatine count, going as high as 2 to 1. In the filtered water before disinfection the ratio in cold weather is about 10 to 1; in warm weather as in the case of the raw water the agar count is highest.

With disinfected water when the temperature is near freezing the gelatine count is considerably higher, ranging from 2 to 1 to 6 to 1. With a rise in temperature the agar count exceeds that of the gelatine, and the agar count in the treated water is very little lower than

that of the untreated water, showing that the colonies developing at body temperature are spore bearing rather than pathogenic.

The table shows the absolute lack of any relationship between the count on agar and the presence of *B. coli*. For instance in February the agar count for untreated water averaged 35 and that in the treated water 25, yet the per cent of positive tests for *coli* in 1 cc. was 39 and for 10 cc. 100, while for the treated water *coli* was absent from all tests in 1 cc. The gelatine counts were 462 and 99.

For March untreated water the agar count was 27 and for the treated water 19, the gelatine being 305 and 27. *B. coli* was present, 23 per cent and 90 per cent 1 and 10 cc. for untreated, and 0 per cent and 10 for treated. For April the counts on agar were practically the same, 17 and 14, the gelatine being 89 and 11, yet in only one case was *coli* present in the treated water, that in 10 cc., and in the untreated water it was present 43 per cent of the time in 10 cc.

Comparison of gelatine and agar 1914

	RIVER		EFFLUENT	FILTERS	FILTERED	WATER BASIN	TEMP.
January	33,900	.....	.....	.....	227	15	36
February	17,250	892	462	35	99	25	36
March	21,900	354	305	27	27	19	35
April	4,950	260	89	17	11	14	51

B. coli communis

Per cent positive tests

	RIVER		EFFLUENT FILTERS		FILTERED WATER BASIN	
	1 cc.	*10 cc.*	*1 cc.*	*10 cc.*	*1 cc.*	*10 cc.*
January	100	100	.....	.....	6	16
February	82	100	39	100	0	13
March	7	100	23	90	0	10
April	8	100	3	43	0	3

MR. W. U. C. BATON: The author has read Mr. West's discussion with interest, and is pleased to find that he is in accord with the substance of the data and ideas advanced in the paper.

The writer once thought that there might be definite relation between agar and gelatine counts which would be serviceable in the interpretation of results. He also recognized the probable value of an agar count if it had a definite relation, by itself, to the sani-

tary quality of a water supply. The results have practically satisfied him that such a condition is not likely to be satisfactorily demonstrated soon.

Data obtained since writing the paper do not seem to add anything. The writer believes in the use of the two counts if possible for the reason that he thinks there is an advantage, in certain instances, for a better interpretation. In any case the diagnosis must be made carefully and in accord with all the known facts. The more facts known both analytical and conditional, the better the final opinion will be. The interpretation of water analyses has certainly not reached a point where it is safe to use "Rule of Thumb" methods based on mathematical calculations.

Mr. West's findings of widely varying ratios of gelatine and agar counts and also lack of relation to *B. coli* impresses this idea a little more strongly. Doubtless others have found, or will find similar results. The question of fixed standards, within narrow limits to apply to all conditions, is going to be an equally elusive problem.

Mr. West's deduction as to the presence of spore forming organisms in water which has been treated with a sterilizing agent is of considerable interest. The writer admits that he has not studied this phase as carefully as the question deserves. He is rather skeptical on the after-growth in sterilizing processes and is not so sure that it is entirely due to spores, in certain cases which have come to his attention. There is no doubt, of course, that spores might act in this way. Just what other factors enter into this condition may not be so apparent and it is for that reason that the writer wishes to make a rather exhaustive study.

It is to be hoped that all who have data on the use and interpretation of agar and gelatine counts will not hesitate to publish them so that such data will be widely available.

DISCUSSION

SEWAGE POLLUTION OF BOUNDARY WATERS

By Mr. Allan J. McLaughlin

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, at pp. 24, etc., and presented for discussion at the Philadelphia Convention, May, 1914.

Mr. J. M. Diven: In the last paragraph of Mr. McLaughlin's paper, he says:

> The greatest obstacle to proper operation and control of plants has been the difficulty of securing the right man to place in charge of the plant. The best type of man for this position is a graduate in sanitary engineering. He will not only be conversant with the mechanical details of the plant, but will be able to adjust his chemicals according to the constituents and needs of the raw water. Most important of all, he will be able to make daily bacteriological examinations to determine the efficiency of purification.

That would be all very well if all plants could afford graduates, and if there were enough of the graduates. This is rather a suggestion to the colleges and educational institutions that they might prepare men for this special work with some special course, although this need not necessarily be a four years' college course. The speaker believes that a man could be prepared to do all the necessary work in a very satisfactory manner in a one or two year course, and such a man could be employed at a much lower salary than a full college graduate expects. Such a man could be prepared for this particular kind of work as his specialty. The trouble is that the young college graduate really does not receive a good salary when he first goes out into the world of work, and then about the time that he has acquired some practical experience and is of some value to the plant employing him, he desires a much higher salary, and does not remain with his original employer; he has higher ambitions and the education to accomplish them, but if young men prepared in the way indicated could be employed at from $75 to $150 per month, they would be valuable, and would be satisfied with positions as

managers of filtration plants of moderate size. They would remain for long terms in their positions, so the plants would not be subject to the annoyance of frequent new men in charge, each with his own ideas and hobbies. This, of course, supposes that the man can change his politics frequently enough to hold his job.

MR. EDWARD BARTOW: The young men should make themselves so indispensable that they will be retained by one administration after another, and then there will be no necessity for their changing their politics. The administration and control of water purification plants should be kept out of politics, as Mayor Blankenburg said this morning, and if such a public policy were adopted, it would permit of trained men continuing in service.

MR. W. H. RANDALL: If the young men will come to Canada, they will find that the trained men do not change with changes in administration; they keep their jobs just the same.

MR. F. A. DALLYN: It appears to the speaker that Mr. J. M. Diven rather belittled the significance of Dr. McLaughlin's remark re bacteriologic control that he quoted. It is all very well for Mr. Diven to talk about getting student graduates for $75 or $100 a month, but the fact cannot be overlooked that by employing experienced men of known efficiency a large plant may frequently be saved $10,000 or $15,000 a year for operating and maintenance expenses. When this is taken into consideration it seems absurd to talk about employing boys to do work for which experts are needed. The speaker was convinced that graduates just released from engineering courses are not at all capable of doing such specialized supervision, except under the instruction of one who is much more experienced; but these graduates frequently become very good men after a few years' experience, and if, after training, these men can take care of responsible positions, employers should either give them such positions or else wish them Godspeed in going ahead with the good work in other centers. The employer's organization has grown complete in the meantime and it is a simple matter to fill in with new assistants.

MR. J. M. DIVEN: Answering the last speaker will say that there was no intention of belittling the remarks of Mr. McLaughlin or taking issue with his views. But there are many small filter plants

that cannot afford to have constant supervision by a technically trained man; and for these plants the training of men who are willing to work for moderate salaries would be a benefit. Such plants, should, however, be under the occasional direction of trained men, men to check up the everyday work of the operator, to also give him instruction and expert supervision. But the operator should have sufficient knowledge and experience to make the daily analyses of the water with sufficient accuracy to check up the work of the filters and to know when it was time to call in the expert.

The young college or technical school graduate seldom gets for a start more than $75 to $150; but he will not be long satisfied with a position that pays no more, and will move on to higher things, leaving the filter plant again in the hands and at the tender mercies of a new man, with new ideas and hobbies; one full of technical training, but no practical knowledge. Moreover, as a rule, the young man with technical training wants to get in a large plant where there is greater opportunity to learn, and where he will be working with men of experience who can teach him how to operate a filter plant such as he has ambition to be in charge of some day.

No doubt the technically trained man could effect great saving in the operation of a large plant, but in a plant with a total operating cost of not over $5000 per year, and there are many such, and soon will be many more, he could hardly save $10,000 or more per annum. But the methods which will effect such saving should be introduced into the plant by the consulting expert, who makes occasional visits to the plant and is supposed to instruct the operator in the best methods for handling the particular plant under his supervision.

The speaker was making a plea for intelligent filter operators; men with sufficient knowledge of filtration and water analysis to properly operate a small filter plant, and not soon get to look upon themselves as experts and possible designers of water purification plants; men just for the everyday running of the plant.

MR. F. A. DALLYN: The speaker agrees that it is not feasible to carry men of high technical skill in small plants, because of the excessive cost. He also agrees with Dr. Bartow as to the method to employ in small plants, using of university graduates with experienced supervision and hoped that this method would be fully enlarged on in Dr. Bartow's paper.

MR. FRANK C. KIMBALL: The speaker regrets that he did not hear all of the preceding discussion, but believes that the proper way of handling the matter is, as one of the speakers suggested, to consolidate expert supervision for a given number of plants. A central control could employ one, two or three assistants, as the case might be, at a lesser price than would have to be paid to obtain the same results otherwise. The speaker knows of such a method being very successfully carried out in a number of plants with which he has had personal connection. A consultant was employed, who could be called on whenever necessary to advise on matters affecting operation of purification works and other technical matters. In one case a young man just out of college who was employed at $60 a month, stayed with the plant, and his salary was gradually increased until he became sufficiently expert to go into consultant work himself, but while he was in his original employment, under a salary of from $60 to $100 a month, under the advice of the consultant, he certainly saved the company several times what the arrangement cost them; but such an arrangement, of course, would not be possible in the character of plant referred to by Mr. Diven, where the operating expenses were only $4000, $5000 or $6000 a year. The arrangement to which the speaker referred was in connection with a plant where the operating expenses ran from $40,000 to $50,000 a year, and still it is not what would be considered a large plant. There is no question but that where purification methods are necessary, which, under present day practice, is probably the case in 90 per cent or more of the plants, some supervision is necessary; and while it may be hard to convince the powers that be of that necessity, after they are once convinced they will never go back to the old plan. Of course, the expenses must be kept within reasonable limits at all times.

MR. FRANCIS WARD LANGSTROTH: In Rahway we have a laboratory at our works that cost about $1000. Our engineer was given careful instruction how to make bacteriological tests, he is furnished with the media and everything necessary for making the tests; as he does the work daily, he has become quite expert. He sends a daily report to our chemist in New York City to be checked there. Once each week a sample of the water is sent to New York to be tested and result compared with the report sent from the pumping station. At least once every two months the chemist from New

York visits the plant unannounced. We also have frequent visits from the State Board of Health. Our work being under supervision of an expert engineer in New York City, we have no trouble in carrying on our work in this way.

MR. C. FALLER: The town of Carlisle employs a chemist from Dickinson College. He charges $20 for every analysis he makes.

PROF. J. M. CAIRD: Without desiring to talk shop, perhaps the speaker may be permitted to describe a system with which he is familiar, that is in use in a large number of places. In some instances, as in Rahway, New Jersey, if there is a good, bright engineer employed in the plant, that man can be educated to keep a pretty close record of all the operations and perform very intelligent work. In larger plants the speaker feels that it is desirable to put a college trained man in charge and have the plant operated under his instruction, while at the same time daily report cards or records are sent to the main office and there checked over and tabulated at frequent intervals for more close inspection.

MR. GEORGE R. TAYLOR: The Board of Health of the State of Pennsylvania has overhauled a number of small plants, less than 1,000,000 gallons daily consumption, and in each case has ordered the owners of such plants to send weekly samples to some chemist in some larger town, who is approved by the State Board of Health, and copies of whose analyses must be sent to the State Board of Health for their approval; and if the results are not satisfactory to them, the owner of the plant is so advised. This refers to bacteriological determinations.

MR. J. M. DIVEN: In the method spoken of by Mr. Taylor the samples of water sent away for analysis are not taken by the chemist making the analysis and can hardly be considered reliable. Most chemists decline to assume any responsibility for water analyses unless they personally take the sample. A much better method would be to have the state or other experts visit the plants occasionally and take samples for analysis, thus checking up the work of the operator.

PROF. J. M. CAIRD: Taking samples once a week is a very risky proposition, as many things may happen in a filter plant in a few

hours; therefore a filter plant should be under some technical supervision all the time, and samples should be taken at least for color and turbidity by the operator. If chemicals are going to be used, the water should be tested for the coagulant, to see whether it is working properly and none of it getting into the filtered water.

MR. F. A. DALLYN: In Ontario the Public Health Department has absolute control.

The speaker believes that sending promiscuous samples is an absolutely nonsensical method. The sanitary situation is the real thing that must be examined into, that is, as to whether infection is probable or improbable. In case hypochlorite or other disinfecting agent is being used to protect a doubtful situation, if samples are examined twenty-four hours after being taken, such examination does not really tell you very much, especially if the sample appears to be a good one; it will tell you something if it is bad. The speaker last summer had occasion to check up the administration of hypochlorite at Windsor, where they occasionally have 17 cases of typhoid occurring in one month, and then probably none for a couple of months. A field laboratory was installed to test the effectiveness of the hypochlorite administration. Instead of taking one sample per day, which by some is considered good practice, samples were taken every ten minutes throughout the day. The water was found to be practically sterile up to about three o'clock when, starting with 50 bacteria per cc., it went down to 5, and then went back in another twenty minutes. That occurred on two days. The bacteriologist inquired at the pump house "What are you doing at that time of the day?" The superintendent at the pump house replied "That is the time of the day when they clean out the bleach tanks, wash them out and start them over again." During the twenty minutes when they were not applying bleach they had very bad water. If a single sample were being taken, the analyst would not probably strike that particular time of day once in possibly a hundred times. In Ontario, municipalities can get information from the Provincial Board of Health Bureau who will, upon request, examine into the sanitary situation surrounding a plant and who will discover by analysis the bacteria there are in the water. They can also tell the normal efficiency that the plant ought to show, and probably suggest what improvements, if any, should be made in the administration of purification agents. This is incomparably more

valuable to the superintendent than any opinion based on a few analyses made by an engineer who really does not know anything about the situation other than the analyses. The speaker has in mind a case where some analyses were checked which had been made in a municipal laboratory by a man who did not know how to make media. He was making media which would not permit of bacterial growths, which of course showed the water good, even when it was bad. Such cases will occur where people are trying to do something which they know really very little about.

MR. FRANCIS WARD LANGSTROTH: The speaker does not wish it to be understood that at Rahway they depend entirely upon the bacteriological tests made by the engineer. He is furnished with media, and as he makes the same examinations daily must naturally become familiar with the work, in addition he sends a report card daily to the chemist in New York City who has the supervision of our work. The sample of water that we send weekly to New York reaches our chemist within two hours from the time the sample is taken.

MR. SHEPPARD T. POWELL: There are a great many plants that cannot afford any kind of a chemist, because they are too small; yet some of these plants, it would seem, should have some kind of scientific supervision, and the only way to do this is to train the engineers who are in charge of the plants. This can be done with small plants by employing a supervising chemist or sanitary engineer who will occasionally go over the work done at the plants and check up the operator who is in charge.

PROF. J. M. CAIRD: The proposition of sending samples away weekly, or something like that, having the water works superintendent take those samples and send them away, is a very risky procedure. Most of the water works superintendents are getting pretty wise, and if they think they are going to be called upon to send a sample away, they are looking for a good report.

MR. FRANCIS WARD LANGSTROTH: In order to avoid suspicion in regard to any of the bacteriological tests made at our works, we have at times sent to our chemist in New York City (unknown to our employes) several samples of water for him to examine and compare

the results with the daily report sent from our works, and they have always compared favorably. Any water plant that suspects anything wrong should have such tests made.

MR. W. H. RANDALL: In regard to trained men being affected by political changes of administration, it very rarely interferes with any trained men in Canada. As to the question of sewage and purification of same, the gentleman from Ontario is aware that we have taken every precaution in Toronto, and have employed experienced or trained men in every case. We find it necessary in a city like Toronto to take every possible precaution, and we try to benefit by others' experience and this week our city council is taking a trip through the United States in order to visit plants where there are sewage systems and disposal plants, to satisfy themselves and to gain experience in connection with that matter.

MR. ALEXANDER C. POTTER (*by letter*): Dr. McLaughlin's point is well taken when he refers to the need of adjusting the balance between water purification and sewage treatment. The writer calls attention to a city in Pennsylvania where a sewer outlet discharges untreated the sewage of about 4000 people, less than half a mile above the water works intake.

The doctor characterizes an incompetent filter operator as an assassin. Is such a man any more so than city officials who, year after year, tolerate conditions such as outlined above to exist?

Is it false security to rely upon the faithfulness of the men in charge of the purification plant? It puts too great a responsibility upon them, faithful as they may be. It is true that, since the installation of the purification plant five years ago, there has been a greater reduction in the death rate than in any other city in the country to my knowledge. The potential danger is still there, and the writer has urged its removal without success.

Dr. McLaughlin's allusion to some views on sewage purification is also timely. The sooner we get away from thinking that sewage must be brought to a drinking water standard, the sooner we can hope for a rational solution of the sewage disposal problem and its more general adoption. In the long run, we can no more frighten people or cities into the adoption of sewage disposal than we can frighten them into religion. The advocacy of a rational view on the matter will bring surer and quicker results.

DISCUSSION

REMARKS ON THE THEORY OF THE PITOT TUBE

By N. W. Akimoff

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, at page 81, and presented for discussion at the Philadelphia Convention, May, 1914.

Mr. J. W. Le Doux: There has been recently a large amount of discussion of the apparatus known as "Pitot tube," the points of greatest interest being the shape and arrangement of the openings; the methods of calibration; the influence of disturbing factors; the formula of flow, particularly as to the term "g" representing the acceleration of gravity, and the constancy of the coefficient throughout the range of the velocity.

In regard to the first it would seem to the writer that as any particular form requires calibration, that which is the simplest and easiest to handle, offers no material obstruction to the flowing water and produces the highest deflection of head for a given velocity should be the most satisfactory.

It has been held that the results are different if a tube is moved in still water from what they are if the tube is stationary and the water moves. It is hard to see how this can be so providing the conditions are alike in each case, for instance: if a long column of water of the same uniform cross section be used for each determination. If a Pitot tube be made to advance at uniform speed through the center of a canal of uniform cross section, the coefficient thus determined should be the same as if the Pitot tube were stationary in the same relative position and the column of water advanced at the same velocity. If, however, the coefficient were determined under the first of these conditions and afterwards placed in a circular pipe under pressure, it is conceivable that the coefficient would be different, although if moving and still water determinations could be made for the pipe itself, the results might be the same.

The influence of disturbing factors, such as the proximity of fittings

or variation in the shape of the conduit or pipe, can never be allowed for in advance, and the proper thing to do is to avoid them as far as possible.

The formula of a Pitot tube, as well as that of the flow through all orifices or contractions in a pipe, is almost universally recognized to be that of a parabola, which is the simplest formula of a conic section, there being but two terms and two variables, one of these being in the first power and the other in the second. The first variable is the head or pressure, and the second the velocity, or quantity flowing. This parabola formula can be placed in the form of

$$v^2 = c\,h, \text{ in which}$$

h is the head
v is the velocity
c is a constant.

If this formula is true and c is a true constant, it is only necessary to obtain the value of h and v experimentally which will determine c by calculation, and when this is once found it is good for all other values.

As the formula is one of bodies moving under the action of gravity, it is evident that the constant is influenced by the term "g;" that, however, need not concern us as long as we have to determine the constant anyway by experimental methods, and it is very important that this determination be made under such conditions as will obtain in subsequent practical use.

If the formula is rational and universal, it will apply throughout the entire range of the velocity, but from all the experimental data with which the writer is personally familiar, there seems to be evidence of variability, which, however, is so slight that it does not affect the results except at low flows. Whether this variability is due to viscosity of the liquid, friction, capillarity, cohesion, etc., or to the fact that the parabola is not the true formula of flow is not at present known, but for practical purposes the formula of the parabola is satisfactorily applicable for material velocities.

DISCUSSION

EQUITABLE HYDRANT RENTALS AND BETTER METHODS FOR APPORTIONING FIRE PROTECTION COST

By John W. Alvord

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, at pp. 95, etc., and presented at the Philadelphia Convention, May, 1914.

Mr. Alexander Potter (*by letter*): The writer heartily endorses the plea of Mr. Alvord for more equitable hydrant rentals and better methods of apportioning fire protection costs, and regrets his inability to take part in the oral discussion of this paper. In the opinion of the writer Mr. Alvord's suggestion is undoubtedly a step in the right direction but does not wholly cover the difficulty, for the question of the city's added burden for fire protection must still be considered every time an extension is made to the piping system.

The writer is of the opinion that the fixing of a general tax-rate for fire protection will wholly obviate the difficulty which now exists in the hydrant rental method of payment.

Of course, the contract with the water company must contain proper provisions for the construction of extensions of adequate size when demanded. Such a provision is not difficult of enforcement.

As forming a proper contribution to the discussion of Mr. Alvord's paper, the writer presents extracts from a report submitted by him to the city of San Antonio, Texas, in June, 1912, but which has not been submitted heretofore to any technical paper. The writer's suggestion in this instance received the endorsement of the company's engineer, Mr. Leonard Metcalf.

There is, perhaps, no subject in connection with the furnishing of water to cities in which there has been more divergence of opinion than that of the method of paying for the service rendered for fire protection, both public and private.

HYDRANT RENTAL NOT PROPER METHOD

The time-honored custom of paying for fire protection at so much per hydrant is antiquated and unjust, both to the water company and to the city.

It is a well known fact that any reasonable price charged for a fire hydrant is normally far in excess of the value of the water likely to be taken from that hydrant in the course of a year for fire protection; consequently, there is a feeling that the price is unjust and unfair to the taxpayers. On the other hand, if fire protection is omitted, the cost of a plant adequate to supply water for private consumption would be approximately half of the cost. The amount of this added cost for adequate fire protection varies with the size of the city. In a small plant, say from five to ten thousand people, this cost probably will be approximately 60 per cent of the total cost of the plant; whereas, as the city increases in size, the extra cost of providing the piping system and pumps of adequate capacity to meet the most exacting fire demands, will probably increase the cost of the plant 15 or 20 per cent. Of course, that is on the assumption that the plant has actually been built to meet this dual demand, and is not simply assumed to be capable of furnishing fire protection. Fire hydrants located at uniform distances along the mains imply, but do not necessarily insure, adequate fire protection.

FALSE ECONOMY IN ORDERING HYDRANTS

Another serious objection to paying for fire service per hydrant is the economic tendency ever present in every municipal council throughout the country to limit the fixed expenditures for all city needs to the lowest possible amount. City officials are not likely to order the water company to place one hundred and fifty hydrants if they believe that one hundred hydrants will carry them through. As there can be no absolute way of fixing the blame for inadequacy in fire protection, the tendency is to play for the popularity which comes to him who keeps down taxes and trusts to good fortune that no conflagration will result from the inadequacy of the fire protection service. You therefore see that both from the company's standpoint and from the city's standpoint, the payment of fire protection at so much per hydrant is an erroneous one.

In San Antonio, the amount paid the water company at present for all public uses is $24,000. On any reasonable and ordinary basis for charge of water the city of San Antonio uses no less than $10,000 worth of water for street sprinkling and other public uses, leaving $14,000 for the charge for fire protection. There are about 1309 fire hydrants at the present time, which makes the charge per hydrant for fire protection $10.70; for all purposes, about $18. This forms so small a percentage of the total income of the water company, less than 4 per cent, that it is seen that the water consumer pays practically the entire cost of fire protection, and the non-resident taxpayer and the owner of unimproved property gets off, to all intents and purposes, scotfree from any charge for the benefits derived from the introduction and maintenance of a system of water supply. Not only this, but the water company being taxed, as it is, both on the value of their plant and for doing business in the state,

the amount contributed by them to the city and county treasuries, lessens the taxes which would otherwise have been paid by the non-resident property owner and by the owner of vacant property. I think it will be admitted by all that an up-to-date water plant in the city is of inestimable value to the non-resident taxpayer as well as to the owner of unimproved real estate, and when we consider that only 4 per cent of the income of the water company is received from the general taxes, to which alone the non-resident taxpayer and vacant lot owner contribute, it will be seen at a glance how the water consumer and small householder is arbitrarily imposed upon for the benefit of the non-resident property owner and the owner of unimproved real estate.

VALUE OF FIRE PROTECTION PER CAPITA

From personal investigation of the question of fire protection, it may be set down as a general rule that water for fire and other purposes will average $1 per capita, with a variation as high as 40 per cent above or below this sum, depending upon the local conditions in any particular city. As will be seen in another part of this report, the conditions in San Antonio are such that the minimum limit under this rule should prevail as the maximum charge in San Antonio; that is to say, a reasonable charge for water for all public uses should be 60 cents per capita; or, on a basis of 100,000 population, $60,000 per year, instead of $24,000 a year, the present amount collected by the water company for this service. . . . .

METHOD OF FIXING PRICES FOR FIRE PROTECTION

As fixed in San Antonio, the price for fire protection is unfair both to the city and to the company. It is equally unfair to absorb this entire fire protection charge in the rates. It also discriminates against the resident water consumer in favor of the non-resident taxpayer and the owner of vacant property in meeting the city's just expenses for fire protection. It becomes necessary, therefore, to devise some other means for the proper apportionment of this cost of providing the city with water for public needs, and I can conceive of no better plan than that a tax should be fixed upon the assessed valuation, which automatically and properly increases from year to year as the assessed valuation increases. The water company must be compelled to construct mains of adequate size to meet the growing demand of the city, and there should be no limitation as to the number of fire hydrants which the city may place upon the city mains. It is considered good engineering practice to place an average of eighteen hydrants per mile upon city mains in the congested district, and ten per mile outside this district. The cost of any increased number of hydrants over this average amount should necessarily be borne by the city. The city would be the direct beneficiary of an increase in the number of hydrants, for the greater the number of hydrants, the closer they will be together, and the less the amount of hose and other equipment the fire department is obliged to carry. The value to the city of this reduction in hose will far exceed the cost of furnishing additional fire hydrants. The shorter the hose length, moreover, the more effective the fire stream. This increase in the

amount to be paid directly by the city represents, roughly speaking, the interest on about $600,000 or $700,000 which the city has a perfect right to demand the company to expend in providing adequate fire protection for the city. As will be seen under the discussion of fire insurance rates, the expenditure of this money on the part of the water company and the payment by the city of this increased amount of fire protection, will result in a saving to the city of at least $150,000 to $200,000 in insurance premiums.

MR. W. C. HAWLEY: Mr. Alvord's paper brings up again a subject which demands explanation and discussion until water works men agree that the present annual-rate-per-hydrant method of charging for fire protection is wrong in theory and in practice, and have substituted for it some just and practical method of apportioning and collecting a proper charge. The method suggested has much merit and can, doubtless, be worked out in many cases in a satisfactory manner, as in the Freeport case, although as will be shown later in this discussion, the rates named appear to be too low. There are cases, however, where the plan could not be used and there are particular difficulties which would probably prevent the securing of satisfactory results in some others. Take the case of two or more municipalities where the supply main passes through one town to reach the other, being part of the distributing system in the first town. Naturally the people of this town will object to paying for a large pipe which is required for the service of the second town. This condition will be more complicated if there are several towns to supply instead of two.

The principal difficulty in carrying out the plan suggested would be the objection of the municipal authorities in the future to the laying of large sized pipes because of the increased charge for fire protection. To illustrate, the company with which the speaker is connected entered into a contract for furnishing fire protection with one of the municipalities which it served, three years ago. The rate charged was based upon the length of pipe in the distribution system within the municipal limits. In order that there should be no question as to the reasonableness of any future extensions of the pipe lines, the following paragraph was put into the contract:

It is further agreed that extensions of the distribution pipe lines of the first party shall be made only upon written application of the owner or owners of property desiring a supply of water therefor, and upon approval of the petition of the said owner or owners by resolution of Boro Council or upon the approval by council of any extension asked for by the party of the first part. When such petition has been approved by Boro Council, the first party

shall proceed to lay the pipe and shall be entitled to include it in computing bills for fire protection at the rates hereinbefore mentioned from the date that the pipe lines are completed and put into service.

Recently an application was made to the water company for a supply of water to a laundry at a point on a street about 100 feet from the main on an intersecting street. There was already laid to a point somewhat beyond the laundry a $\frac{3}{4}$-inch screw pipe. The laundryman asked for a 2-inch service line. He, therefore, petitioned the water company to extend a 4-inch pipe from the main to a point in front of his property and his petition, approved by the water company, was presented to Boro Council for its approval in accordance with the contract. The approval received from the Boro clerk was a brief note saying that Boro Council had approved the laying of a *2-inch* pipe. To this the water company replied that evidently a mistake had been made as the petition was for a 4-inch line and that the supply demanded was beyond the capacity of a 2-inch line, whereupon we were advised, "Boro Council is of the opinion that a 2-inch line is ample." Now, as a matter of fact, Boro Council had no interest in the size of the pipe further than that if a 4-inch pipe or larger was laid it would increase the annual payment for fire protection. We can well imagine, therefore, under the arrangement proposed by Mr. Alvord's paper that when a water company finds it necessary to lay a 20-inch main through certain streets to properly reinforce its distribution system, the butchers, bartenders, druggists and socialists in city council will, in their combined wisdom, decide that an 11-inch main is as large as they care to pay for. This difficulty may be avoided in those states having a public service commission, or, possibly, by arbitration provided for in the contract, but it is likely to be annoying and expensive.

After all, the thing of greatest importance in this connection is that the total sum received for fire protection should be adequate and reasonable. That a return for the hydrants should not be included is obvious. The rate per hydrant should be merely sufficient to cover fixed charges and maintenance on the hydrant and hydrant branch. This should remove any incentive to false economy on the part of the municipal authorities and has resulted, in the speaker's experience, in a material increase in the number of fire hydrants in every municipality supplied under this plan. The amount of the fire protection charged other than for hydrants may

be distributed in a number of different ways, as for instance, on the basis of population, or miles of streets, or area of municipality, or assessed valuation, or upon length of pipe in distribution system. In any case, it is a more or less arbitrary method of distributing the charge and the important thing is that it should not be too arbitrary to be approved by the courts and that it should provide for an increase in fire protection rates as the system is extended that will be reasonable and just. For these reasons, it is probably wise to distribute it in proportion to the length of pipe system and this may be modified as has been suggested in Mr. Alvord's paper. In any case the total is assessed upon the valuation of the property and in this way more valuable property pays an increased amount of fire protection and is not affected in any way by the size of the pipe in the street in front of it. In fact it is not quite clear just how an increased charge per foot of main for a large size can be collected from the abutting property.

Incidentally, the rates proposed by Mr. Alvord seem to be much too low. In the Freeport case he states that 44 per cent of the investment was necessary for fire protection. Taking the cost of a 4-inch pipe line at 65 cents per lineal foot, 44 per cent of its value would be 28.6 cents. Figuring interest, depreciation, taxes and maintenance at a total of 8.5 per cent, we would have on this amount 2.4 cents per lineal foot instead of 2 cents. In the same way, figuring on a 16-inch pipe at $2.50 per foot we find that a charge of about 9⅓ cents should be made instead of 8 cents as given. These figures allow nothing for profit and do not take into consideration any portion of the plant except the pipe.

Applying the rates given to the pipe in the Boro of Wilkinsburg, Pennsylvania, a total length of 29.4 miles, would give a total revenue of $5135, whereas if there was an average of seven hydrants to the mile at a rate of $30 per hydrant, the hydrant rental would amount to $6150 per year. As a matter of fact, on the rate which is being charged, $275 per mile per year, or about 5.21 cents per foot, we are collecting $8087 plus $6 per year per fire hydrant, and these rates are only about half of what the service actually costs. It seems evident, therefore, that the rates stated are considerably too low for the ordinary water works plant.

A method of charging a rate per mile of distribution pipe system was mentioned in the paper presented by Messrs. Metcalf, Kuichling and Hawley at the Rochester meeting (see *Proceedings Am. W. W.*

Assoc., for 1911, p. 65). The case cited was that of the Pennsylvania Water Company and the rates at that time were before the court for a determination of their reasonableness. They were approved by the Court of Common Pleas of Allegheny County and later in an opinion handed down in January of this year, by the Supreme Court of the State, and they are now in force and two contracts based on these rates have been approved by the State Public Service Commission. This, so far as the speaker knows, is the first practical application of fire protection charges on this basis and it may be of interest to note that this method of charging for fire protection was first proposed, so far as the speaker knows, by Mr. George S. Davison, Mem.Am.S.C.E., Vice-President of the Pennsylvania Water Company. This method seems to have appealed to the Railroad Commission of Wisconsin as a similar method of payment in the case of extension of mains when ordered by the city was approved by it in the Green Bay Water Company case, decided October 14, 1913.

The discussion of this matter at the present time is largely academic. It is valuable, however, as pointing out the gross unreasonableness of the rates and method of charging which obtain almost universally in this country today. The first practical step will be for each water company to determine what it should receive for fire protection service and then to take such steps as are necessary to collect it. The days for free service of any kind or for loading one branch of service with the deficit caused by unreasonably low rates on another, are rapidly drawing to an end. Doubtless, it will take much effort to educate our courts, but in good time we may reasonably expect that they will approve the proposition. The municipal plants should not be behind the private water companies in adjusting the rates for fire protection and thereby relieving their domestic consumers. This is done in some cases now through the raising of interest and sinking fund charges by general taxation or by the payment of a flat rate for water used for municipal purposes. If the results in such cases are equitable between the various classes of service it is an accident. The amount raised by direct taxation should be properly estimated and charged for as service rendered. If this was done, it would result in many cases in a reduction of rates to the domestic consumer. In these days, when economy and efficiency are the watchwords, there should be no objection on the part of the taxpayers to the putting of their plants on a just and proper financial basis.

MR. J. N. CHESTER: In regard to Mr. Alvord's paper, the speaker has applied his basis to five different plants, and his conclusion is that, while the method may be a good one, the unit price is entirely too low. Take 1.2 cents per inch foot, we will say, 6-inch pipe, for each 500 feet yields $25, which is too little. Mr. Alvord shows in his paper how the Wisconsin Commission has allowed about 50 per cent of gross revenue, in cities of from 10,000 to 15,000, for fire hydrant rentals. Applying Mr. Alvord's maximum price of $8 per hydrant and $\frac{7}{10}$ cent per inch foot, in the case of Jefferson City, Missouri, it would produce $5600 out of say $50,000 gross, which would not be over 12 per cent, instead of the 50 per cent indicated by the paper as being about the proper thing. Now applied to the Edgeworth Water Company, it increases the hydrant rental about 50 per cent. The speaker does not find, in any of these applications, that it will produce over 12 per cent of the present revenue applied in its maximum; therefore he is of the opinion that it needs to be multiplied by three or four, instead of squaring it, or some other method, as Mr. Barnet suggests. The speaker has always liked the method outlined by Mr. Hawley, as being the most equitable, for, it seems to him, that a frontage tax would be the most equitable distribution of fire protection.

The following table gives the results of the application of Mr. Alvord's method in five cities as compared with the present income for the same water works:

PLANT	1 NUMBER OF INCH-FEET IN MAINS	2 INCOME AT .4 CENTS PER INCH-FOOT	3 INCOME AT $5 PER HYDRANT	4 INCOME AT .7 CENTS PER INCH-FOOT	5 INCOME AT $8 PER HYDRANT	6 TOTAL INCOME BY ALVORD METHOD AT LOWEST RATE COL. 2 + COL. 3	7 TOTAL INCOME BY ALVORD METHOD AT HIGHEST RATE COL. 4 + COL. 5	8 PRESENT INCOME FROM HYDRANTS	9 PRESENT RATE PER INCH-FOOT AFTER DEDUCTING $5 PER HYDRANT	10 TOTAL PRESENT YEARLY REVENUE	11 PER CENT OF REVENUE FROM FIRE HYDRANTS
Capital City Water Co.	556800	$2227	$755	$3898	$1208	$2982	$5106	$5600	$0.0087	$48738	11.5
Edgeworth Water Co..	370600	1482	320	2594	512	1802	3106	1920	0.0043	20566	9.4
Monongahela Water Co	544000	2176	225	3808	360	2401	4168	1800	0.0029	22609	8.0
Ohio Valley Water Co.	2511800	10047	1865	17583	2984	11912	20567	15145	0.0053	158259	9.6
Johnstown Water Co...	1318600	5274	870	9230	1392	6144	10622	4350	0.0026	195874	2.2

DISCUSSION

TESTING OF CHECK VALVES

By Mr. J. Walter Ackerman

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, at page 90, and presented at the Philadelphia Convention, May, 1914.

Mr. George Houston: What kind of check valves are usually installed in that class of lines? We have a number of auxiliary water supplies which we are very desirous of protecting our system against, and would be very much obliged if some of the members could give us some information as to the best type to use.

Mr. J. Walter Ackerman: The check valves we use are designated by the underwriters as a "special sanitary check valve." There are two or three forms that are being made and have passed the underwriters' test. The principal difference is that the valves are made in tandem, or at least they are assembled in tandem, with sufficient clearance between them so that any ordinary stick or anything of that sort that might get in the mains would not keep both of them open at one time. All the moving parts, the seat ring, the clapper, the arm of the clapper, the hinge pin and the socket of the hinge pin are bronze, with a rubber seat; the rubber being somewhat like that used in the Grinnell dry valves. The clearance is also made very liberal so that any of the tuberculations on the inside would fail to reach the clapper, so that it would always be perfectly free. The inside of the valves is also coated with some sort of asphaltum paint or similar product to prevent tuberculation as far as possible. A letter to the underwriters will give you a list of the manufacturers that make these "special sanitary check valves," showing what ones have been O.K'd by the underwriters.

Mr. George Houston: Just in reply to the kind information given, would like to say that one object in asking the question was

for the purpose of bringing out the sense of this Association as to whether or not single clapper check valves are considered sanitary; for the reason that the matter has been brought up in our city a number of times, in an effort to compel the people having auxiliary supplies to put in the sanitary valve; and we have been prohibited from having our way in the matter and they still keep on using single clapper check valves. So we wanted the backing of the Association in the proposition.

MR. J. WALTER ACKERMAN: This subject received a great deal of consideration at one time in our department. Our own idea was that the single clapper valve was practically useless. An examination of the same proved that fact. They were so bad in fact that the Board ordered all auxiliary supplies disconnected, which of course brought forth a great deal of criticism from the manufacturers, our town being a large manufacturing town; but it was not until after we had been assured by some of the best men of the country that we could perhaps secure positive results by the adoption of a sanitary check that they modified that clause; and it took us nearly a year and a half to secure valves at that time that would pass the test prescribed.

As to the question whether a single valve is a sanitary valve, if you have to have an auxiliary polluted supply you cannot throw too many safe-guards around it. The old practice was with single sanitary check valves to bury them in the ground the same as you would a gate valve; but at the present time we require that all the check valves be placed in accessible vaults, d ined and cleaned, so that any man can get into them at any time. Personally the speaker considers that the single check valve is entirely unworthy of consideration.

MR. F. A. DALLYN: In Ontario there is a prohibition from the Provincial Board of Health against the use of check valves; that is, there is no connection permitted between the auxiliary supply and the city main. The connection is cut off and sealed. In factories, barrels for cooling purposes, etc., may be filled from such supply, where the feed to the tub is carried to the bottom in order that only dirty water is accessible to the workmen; they do not care to drink this. There are several steel works where it is necessary to have an auxiliary supply in order to cool their rolls. In such cases they

are forced to put in drinking fountains fed from a safe supply; the fountains operate continuously and supply cool water. So far as Ontario is concerned, the question has been solved. The use of check valves in not allowed and no difficulty is experienced.

PRESIDENT THOMAS: That is the safest rule to follow.

MR. E. E. DAVIS: In our city we do not allow connections between the two services. We have only one, and that is not a check valve, but simply a gate valve. We were asked by the chief officer how we knew whether that valve had ever been opened, and told him because that valve turned the opposite way from the other valves in that plant, and when a man went there to open it he would attempt to turn it the wrong way and would break it, and in that way we would catch him.

DISCUSSION

USE AND BENEFITS OF PRESSURE RECORDING GAGES

By J. M. Diven

Printed in Journal of the American Water Works Association, Vol. 1, No. 1, March, 1914, at page 103, and presented for discussion at the Philadelphia Convention, May, 1914.

Mr. A. A. Reimer: The use of recording gages is absolutely necessary in any up-to-date system. We consider that in our case one of the most valuable uses to which we have applied them is in our fire flow test work. By placing a recording gage in any group of hydrants to be tested we obtain a complete record of the loss of pressure in that group without having to station a man at every individual hydrant in the group. Thus we will eliminate the use of a large corps of men and with two or three men we can run these fire flow tests and our results check very nicely with the results obtained by the representatives of the National Board of Fire Underwriters, who made a recent survey in East Orange.

With reference to packing away the charts, the plan of taking out one typical chart each month, and any special chart with the necessary notes on that special chart, reduces the space required very largely.

Mr. J. M. Diven: No objection was made to filing away the charts so that they can be referred to, but it was merely suggested that the diagrammatic form was so much more convenient for reference as you have before you the record of the entire year, or even a series of years. Every chart should be preserved as an evidence and record of that day's pressure conditions. Averages or typical charts would be of no value in a law suit.

Mr. A. A. Reimer: We do not think it necessary to keep the charts indefinitely. Charts that are ten years old are obsolete, and

there is not one chance in ten thousand that there will ever be occasion to refer to such charts.

MR. J. M. DIVEN: I have studied some that were thirty years old, and found them interesting. But suppose there is a limit to the time charts would be valuable, as the averages answer for the purpose of studying general conditions. However, like to be ready for the ten thousandth time.

MR. J. WALTER ACKERMAN: In connection with this subject the author spoke of the ragged condition of the charts that sometimes exist. In our own system, our attachment for the office chart happens to be in the down-town district where the elevators are located; and in trying to eliminate the effect they have on the charts we took an ordinary hot water tank and placed it in the basement of the office building, arranged by-pass connections in such a way that we could use that for an air-chamber or a cushion, so that the actual surge on your elevator systems does not give the gage the momentary thrust, but the air-chamber absorbs it, while any direct change in pressure gradually shows up. The speaker does not know whether anyone has had that particular experience or not, and just mentions it as one of the things that can be added to a recording gage that will obviate some of the difficulty.

MR. J. M. DIVEN: That is a novel suggestion, but does it not do away with one of the uses of the gage, by failing to record the water hammer caused by hydraulic elevators? That is good information to have; the very fact that that gage is fluctuating is an indication that something is abnormal on your system; that you have a 30 or 40 pound water hammer, and you do not want to eliminate the record of it; but to try to find its source and then correct it.

MR. J. WALTER ACKERMAN: But if you have a number of elevators that are already destroying your gage record, you want something to try to eliminate that.

MR. J. M. DIVEN: Your gage is telling you that what you want to do is to get rid of those elevators, or else put in a bigger main for them, one large enough to supply them without undue fluctuation of pressure.

FIRE ALARM ATTACHMENT FOR RECORDING PRESSURE GAUGE

By W. E. Haseltine

Several years ago the Ripon Light and Water Company got into a serious controversy with the officials of the city of Ripon owing to a claim of inadequate pressure at a fire. Fortunately, the company had in service a recording pressure gauge by which it was able to prove to the satisfaction of experts engaged by the city to make an investigation, that the fault did not lie with the company's pressure but with the length of run of hose and the attachments made by the fire department.

This decision created so much hard feeling among the city and fire department officials that the company was subjected to a series of petty persecutions in the way of so-called tests and complaints with regard to the length of time it took for the company to furnish fire pressure after an alarm was turned in.

The Ripon Light and Water Company furnishes domestic service by pumping into a standpipe, and fire service by shutting off the standpipe and pumping directly into the mains, and it seemed most desirable to have some method of proving beyond question how long it took to furnish this direct pressure after an alarm was turned in. For this reason the attachment described below was devised and put into service, and its operation as well as its effect upon the company's relations with the city have been most satisfactory.

As will be seen in cut No. 1, it consists merely of an auxiliary hand "A" turning on a sleeve on the same axis as the recording hand of the pressure gauge and adjusted to mark coincidentally therewith. Under normal conditions this hand draws a perfect circle near the outer edge of the chart, but when an alarm of fire is turned in, a small electro magnet operating upon the armature attached to this hand jerks it to one side, making a mark at right angles to the regular curve, indicating indelibly upon the chart the exact instant at which this alarm was received. By observing the chart it is possible, without question, to determine what the pressure was at the

moment the fire alarm was turned in and how long thereafter direct pressure was furnished.

The connection with the fire alarm system is made through a regular telegraph relay, the magnet on the gauge being operated by a single dry cell. Figure No. 1 shows upon the gauge a chart which

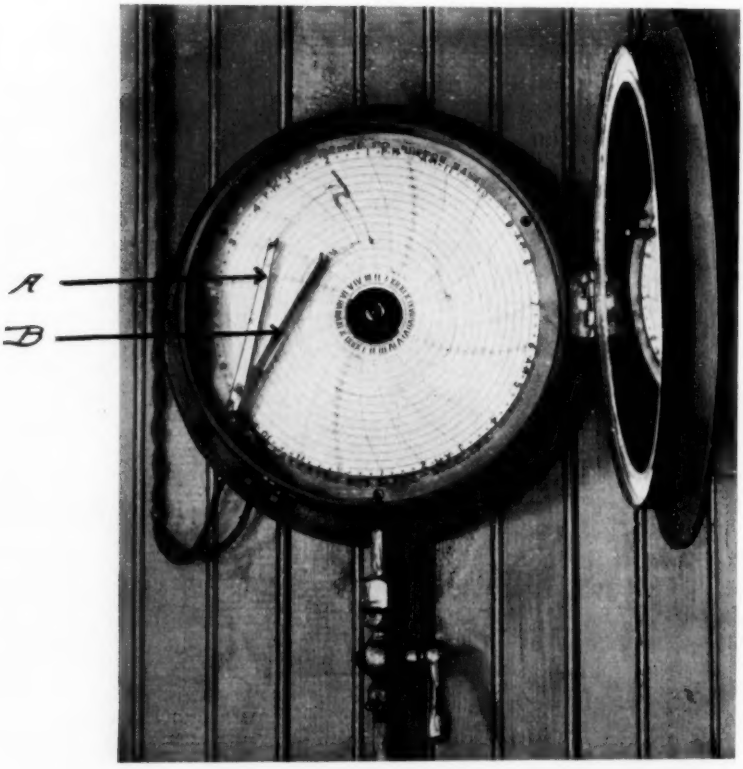


FIG. 1 FIRE ALARM ATTACHMENT FOR RECORDING PRESSURE GAUGE

A—Fire Alarm Hand
B—Pressure Gauge Hand

records a fire, the pressure furnished, the time of turning in the alarm the exact pressure at the time the alarm was turned in, the time direct pressure was furnished and the amount of the direct pressure.

Figure No. 2 shows in diagrammatic form the necessary connections for the fire alarm hand.

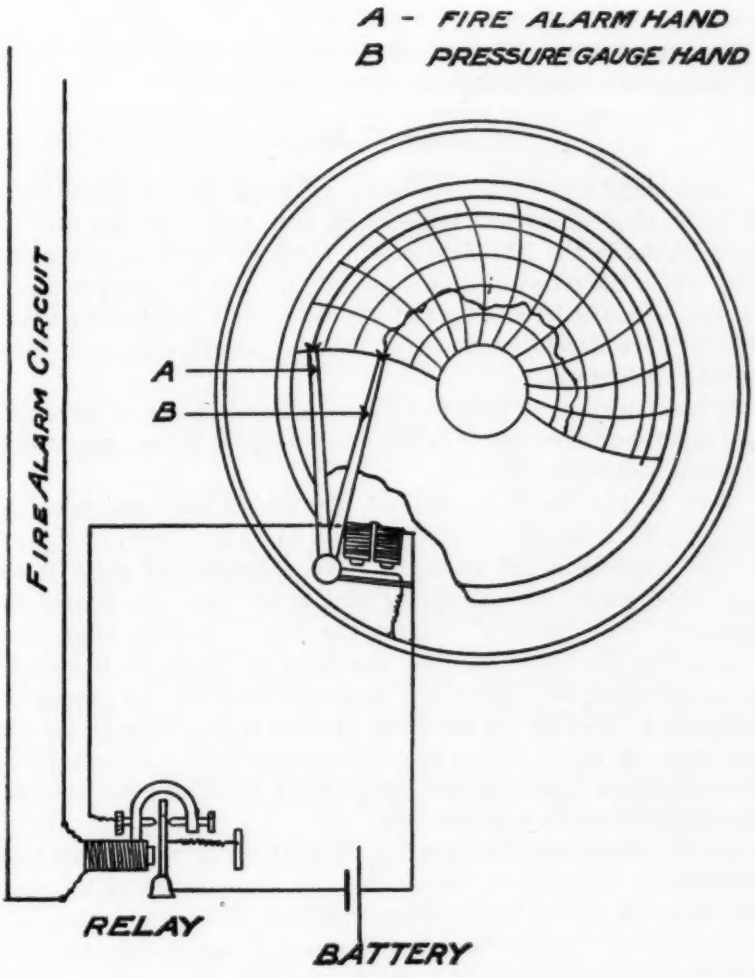


FIG. 2

This attachment for the gauge was made by the writer in about half a day, using the magnet out of a small electric bell, the total cost of the material, including the relay, being about $2.

CONSERVATION OF POTABLE WATER AND THE DUAL SYSTEM OF DISTRIBUTION

By Henry C. Hodgkins

Many members of this Association will recall the first installations of mechanical filters and those of us who undertook the work of installations in the late eighties will recall the spirit of incredulity with which the propositions were received. The whole germ theory of disease was in its infancy and the real science of filtration can be said to have developed coevally with the investigation and classification of bacteria.

It has been our fortune to follow the development of both slow and rapid sand filtration from the first principles to the present high scientific and efficient results.

With all that has been attained, the field is large and much remains to be done and many difficulties to be overcome.

The sanitarians and engineers have accomplished great things and have worked so persistently that every home has caught the slogans: "Swat the Fly," "Squirt the Flea," "Oil the Mosquito," "Coagulate the Bacteria," set the different tribes at warfare, a thousand times more fierce and numerous than the war among the Bulgarians. Put all the survivors to sleep with a little Hypo, and still when we return to our favorite beverage, with a little water on the side, there is perched the eternal germ, blinking away from the drowse to which he was chlorited.

In all seriousness the question of pure water is growing more complicated and difficult every year. In the language of the opening sentences of the lecture of a celebrated Brooklyn divine, "The United States has now 95,000,000 of people and shortly will have 500,000,000 of people." Is it any wonder that the question of food supplies is appalling and that the greatest food supply of all, pure water, should cause water works men to stand aghast at the problems that confront them? Just for a moment let your mind revert to the great rivers of supply carried by such works as supply Los Angeles, the City of New York, and the enormous proposition for the little city

of Ottawa. Just try to grasp what all this means and where it is leading us as the country grows toward its 500,000,000 of population. Think of meeting all this flood and carrying on a warfare of bug extermination. And all for what purpose: simply that we may have a little pure water to drink as we enjoy an evening's sociability.

All of the waters of the Great Lakes have been condemned by an international commission. Not a river in all this broad land has escaped the censure of the sanitarian. Conditions are not improving but constantly growing worse. All the disposal plants that are being, or may be constructed will only mitigate the trouble from sewage to the extent of preventing its being branded as a nuisance. The warfare once started, must continue in increasing proportions with recruits coming faster than they can be annihilated.

The totals of water consumption are increasing so enormously that potability for the entire supply is being considered by a large portion of consumers as shrouded in doubt. Is it not time that we should recognize the tremendous size of the problem and proceed to furnish water of unquestioned purity, where pure water is required, through a separate or dual system? The writer advocated the proposition before this Association 16 years ago, and now as then, he hears the murmur that the plan is impracticable, unscientific and contrary to the established principles of hydraulic engineering. On the other hand he hears the call of the thirsty from the time of Hagar crying in the wilderness, down through the ages to the present, when thousands upon thousands are turning from the faucet to the bottle for their water, and the cry is becoming more and more insistent for pure water to drink.

The daily average consumption per capita for cities in this country will run from 100 to as high as 200 gallons. Very few large places will average less than 100 gallons. The maximum per capita consumption will run from two to four times the average. The average daily consumption per capita for domestic purposes will amount to from 25 to 30 per cent of the total average, and the amount required for culinary and drinking purposes will amount to from 3 to 5 per cent of the total. The amount of potable water thus required is very nearly a constant quantity from day to day. According to a paper presented to this Association a year ago there were some 400 water works filtration plants in this country, about the same number as there were water works when the writer started in the business. These filtration plants cost from 12 to 20 per cent of the total cost

of the remaining portion of the water works in the case of mechanical filters and 20 to 30 per cent in the case of slow sand filters. In Pittsburgh, the estimated cost was 30 per cent and in Toronto 20 per cent of the previous cost of the works.

In a city of 100,000, Mr. Leonard Metcalf estimates the cost of that portion of a distribution system due to domestic consumption at 22 per cent, that due to industrial consumption at 32 per cent and that due to fire protection at 47 per cent. If the division is carried farther that portion due to culinary and drinking purposes would be about 4 per cent.

If the distribution system could be separated into distinct systems and at the above proportionate costs the problem of dual systems would be easy. But such is not the case. The cost of a dual system in terms for a complete system would vary widely, but as a general proposition it is a fair statement that a separate system to supply the inhabitants of a city with potable water would cost from 25 to 30 per cent of the distribution system as generally constructed. In other words that the cost of the dual system would be from 70 to 150 per cent of the cost of the filtration plant, varying widely according to conditions and according to which system of filtration is used.

There is a wide range in the cost of filtering water. Making due allowance for maintenance of plant, interest and depreciation, the cost would probably fall between 1 cent and 1.5 cent per thousand gallons. Assuming a cost of 1.2 cent per thousand gallons, the cost of filtering

1,000,000 gallons per day would be	$12.00
40,000 gallons per day would be	.48
Difference per day due to filtration	11.52

That is, if instead of filtering all of the water, only the portion furnished through the dual system was filtered, the saving in the cost of filtration would amount to $11.52 per million. From this would have to be deducted the interest, depreciation and maintenance of the dual system which in a medium sized city would require not to exceed half of this saving, leaving the remainder for the additional cost of administration and saving to the department.

The pure water should sell at a much higher rate than the raw water for two reasons: first, to provide ample revenue to cover all charges due to the dual system, including service pipes and meters;

and second, the price should be high enough to prevent the use of pure water for other purposes than those intended.

These figures are merely illustrative but they are sufficient to show that the dual system is not impossible from a cost point of view, but that it is entirely feasible and in many instances the solution of a very difficult situation.

It is not claimed that the dual system should be universally adopted, but in places where there is a supply of naturally pure water sufficient to meet the culinary and drinking requirements it is urged that it be supplied through a separate system, leaving the larger requirements to be furnished from the nearest and cheapest source of reasonably clean water.

There are many instances where towns have outgrown their water supply; the present supply being excellent in quality but insufficient in quantity. Just such an instance exists in the writer's practice. The demands have increased beyond the supply and the capacity of the distribution mains. It has been recommended and considered with favor, that a duplicate system covering nearly half of the town be installed, furnishing a water more suitable for manufacturing purposes but not fit for drinking; the original distribution to supply all of the needs of a portion of the residential section from the original source, with the smaller mains extended to all parts of the town, supplying all the inhabitants with the excellent drinking water; it being the expectation that as the city grows the dual system would be extended until the entire city is covered.

Because the industrial growth of the town has caused a demand beyond the capacity of the supply, but which is still sufficient for all house supplies for even a much larger town, should the best of nature's supplies be discarded and replaced by a filtered supply?

The difficulties of supplying the ever increasing demand with a potable water are such that all naturally pure waters should be conserved, and it would seem that it is time that the scientific planning of dual systems should be commenced. It is not the purpose of this paper to criticize work that has been done or that is under way; but to emphasize a new departure in water works construction and management. There is no reason why the bottled purveyors should have the best of the business. Pure water, like other food products, should be conserved and delivered in the best possible manner.

The great argument against the dual supply has been the difficulty of controlling its use. It has been argued that poor people would use the cheaper water, and that many, especially new arrivals in the city, from ignorance would use the contaminated water. Every precaution should of course be taken to prevent the wrong use of either water. The drinking faucets should be of one handsome ornamental design, properly labeled. All other faucets should be of the same and an entirely different and distinctive design. Greater care and inspection of all fixtures would be necessary, which would certainly be progress in the right direction.

DISCUSSION

MR. J. M. DIVEN: It would appear to the speaker that one objection that the author failed to mention is the cost. Would it not be well to investigate and find out whether it would cost more to filter all the water and use all pure water, or to put in a dual system; in other words, would not the interest and depreciation cost on a dual system cost so much as to more than offset the cost of purifying the entire supply? It must also be remembered that with the entire supply purified there would be no danger of people getting the wrong water, which is a danger to be feared from carelessness or ignorance.

MR. J. N. CHESTER: To discuss a paper, of course, is not always to agree with it. The speaker is aware now why Mr. Hodgkins was asking him some questions about consumption and why he was insisting that most consumption was over 100 gallons per capita per day. The speaker cannot agree that a dual system is beneficial or advisable from any practical standpoint; it may be advisable in an exceptional case, but certainly not as a rule. It might be a possibility to be considered in one case out of a hundred, but in the other ninety-nine cases it would be found, upon a thorough investigation and comparison of costs, to be impossible. Let us inquire what our water supplies are today; they are either surface waters, which, to be pure or potable, must be purified, or they are naturally filtered or subterranean supplies, which in most cases are much harder and less adapted to domestic uses in many ways than are surface supplies; that is, they are not as practical. Well water in most cases is purely a drinking water. The water for purely domestic purposes is the filtered surface supply in at least nine cases out of ten.

Now, so far as the cost of a dual system is concerned, the previous statements may be qualified a little by saying that the dual system does exist in most places today, but it is not credited as such by the author of this paper. In Pittsburgh there is pumped to the industries of that town raw water from the river to over ten times the amount of the water that is pumped to the city, and that city is using 100,000,000 gallons a day. Thus you can see what our industries are doing along our rivers. Go to any town, and you will find that the industries that can better use the raw water from the streams are located along the streams.

Let us go a little beyond the Alleghenies and see what the turbidity of the rivers is. What do we filter water for? Because our industries demand purification or clarification of the water supplies just the same as the inhabitants who take the water; and if you draw it out of wells the health officers and state engineers will tell you that they are requiring now that the water shall be kept down to less than one-half of one p.p.m. of iron before they will approve its use and where is the well water that produces less iron than that in its natural state? One of the previous speakers (Mr. Diven), has touched clearly on a vital point in this matter, and that is the cost. Again, the best work of purification is not done by our small plants. Suppose that only the small portion of water that is to be drunk is filtered, are you going to get results from a small filter plant equal to those of a filter of larger capacity? No. And that is one case where wholesale is better than retail as to quality. Mr. John W. Hill, of Cincinnati, years ago brought up the question of distilling all the water, but certainly that would not be practicable, and the speaker has seen very few cases where it could apply. If you had a spring that was thoroughly protected and the water was soft, you might afford to pipe that into the town and use it as drinking water, but if you must purify part of the water and build a dual system, the speaker is of the opinion that the flag that Mr. Diven held up will signal you to stop, because the cost will be prohibitive. Besides that, you will have to place dual faucets, which will be used accidentally, the one for the other, and there will be more sickness and more trouble from using the wrong faucets than would be occasioned by the use of raw water. They are filtering 100,000,000 gallons at Pittsburgh, and are not complaining about it. Very little of that water is used for any purpose for which it is not better filtered than it would be otherwise. On the Mississippi River, the

turbidities run from 1000 to 10,000 p.p.m., what practical use can be made of that water without first clarifying and in clarifying, it must in a large degree be purified.

MR. J. M. DIVEN: There is one point with reference to filtration that Mr. Chester did not touch upon. The small unit might do just as good work as the other, but it would be at considerably greater cost; in other words, your overhead charges, such as chemist, attendants, fuel, etc., would be as great for the small as for the large plant. In one instance within the experience of the speaker there was a perfectly pure water supply for domestic use. It was a delightful water for bathing and drinking purposes, but unsuited for mechanical purposes. The attempt was made to get customers enough to pay for piping this water around the city. The wells were right in the heart of the city, and had sufficient pressure for domestic purposes without pumping. The idea was to supply this water under a dual system for drinking purposes; but the effort to obtain sufficient customers to support the project was unsuccessful.

MR. H. C. HODGKINS: The question of cost is largely guess work, and the speaker will not attempt to say that he has worked it out in detail, but the fact remains that the dual supply in some of our large cities has been seriously considered and is particularly desirable. Take the worst instance that you can pick out, the city of Syracuse; you who have been there know how they boast of their water supply. It has a double conduit line from Skaneateles Lake which it will surely outgrow. The manufacturing industries of the city are increasing rapidly. There is a better water for a great many purposes in Syracuse than even the Skaneateles water. The speaker doubts that the cost is the bugaboo; in fact, believes that large industries would require water that can be obtained at less cost than additional water of the same kind. The fact remains that where filtration plants are in operation, the bottled water business is increasing at a tremendous rate. The speaker does not mean to condemn filtration; be believes it to be the thing, but the fact is that the dual business is going on. Take the Black River water supply; you have there a safe water to filter. The speaker does not mean to say that it is not being filtered well, but in competition the bottled water is thriving to a great extent, although no bottled water anywhere can surpass the splendid Adirondack water that is

available for the entire Black River Valley. The question is, shall that eminently pure water, the best that nature provides, be withdrawn from the inhabitants of that rich valley in favor of a black water made white by bleaching, or shall they have pure water to drink? The speaker doubts very much whether it will cost more, but believes that when you come to work it out the balance will be on the other side of the ledger. However, there is no iron-clad rule that will apply. It cannot be decided offhand or there would not be any use for the gentlemen of the profession here represented. The speaker does not contend that it will work out in all cases; but there are places where it is worth consideration and where he believes it will work out very much to the interest of the inhabitants.

MR. FRANCIS WARD LANGSTROTH: New York City has a dual system from 23d Street to the Battery for fire protection, the normal pressure for domestic service is 40 pounds, the pressure of the dual system is 125 pounds, as soon as an alarm of fire is given, this can be raised, if necessary, to 300 pounds, should there be a serious conflagration water can be taken from the river for the high pressure system.

MR. D. D. JACKSON: In connection with what Mr. Langstroth has said the speaker would state that the salt water is not used in the fire protection pipes, but that the Croton supply is the only one that is used for fire purposes. While the salt water is connected, unless in the case of some great catastrophe, the salt water will probably never be used for fire purposes, so there is no dual system in New York City.

MR. P. A. MAIGNEN: There has never been a paper so well presented before this Association as the one we have just heard. In investigating whether a thing ought to be done, the first question is, Is it wanted? The second: Can it be done? And the third: How much does it cost? If, as in the discussion we have just heard, the question of cost is brought up in the beginning, the proposition will never be satisfactorily settled. On the other side of the Delaware, in Camden, they have wells with good water but they cannot draw more than a certain quantity, and therefore if the industrial establishments require more water it must be found elsewhere. The question of a separate line of pipe to supply those industries and the fire

hydrants in the industrial district has been raised and it was proposed that the Delaware River should be scrubbed or submitted to preliminary filtration. This would be a proper solution of the problem.

The question of a double supply of water is indeed a very interesting one. Have we not heard this evening that modern filter plants are so erratic that they must be subject to the supervision of expert chemists every ten minutes. A filter system that requires such supervision should not be allowed to exist. The solution cannot be found by simply examining the sample every ten minutes or every hour, it can only be found in a double system of supply where the best water can be treated with care and the industrial water treated industrially. With one single supply the volume of water is too large to be handled in a satisfactory manner. The speaker has advocated dual canalization for years in the different engineering societies to which he belongs, and in this Association. The city of Paris has a double supply, one of spring water and one of filtered water (which is called "assimilated"). It has been said this evening that large filter plants are better than small ones because more expert supervision can be employed. In the experience of the speaker and that of others, it has been found that small filter units are more safe and more easily handled than big ones and do *not require* constant supervision. The big units may be all right when the water is at its best, but they are all wrong when it is at its worst.

It would seem then as if we are all agreed on the necessity for chemical purification. The question then is to have the engineers and experts find out the best chemical or chemicals to be used for the purification of water, but as this cannot be done everywhere at once it is suggested that in the same way as during times of epidemic, the boards of health and commissioners advise the people to boil their water, they should advise their clients in times of danger to sterilize the water themselves, in their own homes.

MR. FRANK C. KIMBALL: There is one point in regard to a duplicate or dual system which may be deemed a detail, but if so, it is a detail that should require very careful consideration in any city where such a system might be in operation. Without taking any exceptions whatever to anything that has been said as to the necessity for a dual system, the question would at once arise as to its

practicability. The speaker believes that there are a number here who can recall the case at Lawrence, Massachusetts, where in the mills there was a dual system. The city water supply was filtered and there was no objection to it from any point of view for use for drinking purposes or for any other purpose that was necessary. The river water was polluted, but was piped through the mills for ordinary use in washing and for other things. The pipes conveying this polluted supply were very plainly marked, even to the extent of being of different color and style, and were labelled. A penalty was imposed on any employee or operative who used the river water. Notwithstanding this, after some little time this system had to be done away with because the operatives would not, nor could they be made to, keep away from the river water faucets when these happened to be just a little more convenient. This resulted in a great deal of sickness and disease, and in several cases, deaths were traced directly to it. It may be that some arrangement can be made which would make such dual use practicable; but we have this experience on record, which shows what one great difficulty is where two supplies enter the premises both to a very great extent having the same degree of availability, particularly if the use of one is going to cost more than the use of the other. At the present day it is safe to say that the large majority of the people are not educated to understand the difference as between water that cost 10 cents and water that cost, 30 cents to 40 cents. Both look alike to them, and, so far as they are concerned, taste alike, and we cannot at the present time make them see why they should use one rather than the other.

Mr. F. W. Cappelen: It would seem to the speaker that the greatest objection to a dual system, such as Mr. Kimball has referred to, is that it is the duty of every municipality today to furnish an absolutely pure supply of water for the inhabitants. It must be safe, so that a child can drink it, so that anyone can open a faucet anywhere and be safe, no matter whether it is an ignorant laborer or anybody else. It is not sufficient to care for the intelligent people who can afford to have fancy plumbing and fancy indicators, showing them from what pipes to draw the water, but it is the duty of the municipality to protect every inhabitant alike, and see that they are safe whenever they use drinking water. We cannot do that with a dual system, it is absolutely impossible.

MR. P. A. MAIGNEN: It is hard to understand why two spigots are needed in a yard. Why should there be one spigot for good water and another spigot for bad water? Why can they not use all good water when they consume so little of it? If a large quantity of water is needed in a yard for industrial purposes they could easily have a special hydrant which would not be convenient for drinking.

MR. H. C. HODGKINS: Some years ago the speaker presented a paper to this Association, in which he promised to give, later on, a sequel. Those of you who retain your copies of *Proceedings* and who find them valuable, if you will look back will find the history of the water works at Newark, Ohio, and you will find it interesting to give it a re-reading, particularly those of you who may still be operating under franchises. The sequel in that case is that the city built a complete plant covering about 40 miles of street distribution. The original plant, which was constructed under specifications prepared by an eminent engineer and supervised by the city, covered about 30 miles of streets; so that in that case you have a thriving city of about 25,000 or 30,000 population, which has two systems of distribution covering at least 75 per cent of all the streets. Now, being the owner of a dual system, would it not be the part of wisdom to supply pure spring water through one system and the generally clear river water through the other system?

PURIFICATION OF WATER BY THE ULTRA-VIOLET RAYS[1]

By M. von Recklinghausen, Ph.D.

It is a matter of common knowledge nowadays that the ultra-violet rays have a strong bactericidal power. Within the last few years this power of annihilating microbes by ultra-violet rays has been applied for freeing water of germs and a new industry has sprung up which produces water purifiers that make use of this new principle to sterilize water for drinking and other purposes. As this system is being applied successfully to large water plants it is of interest for the professional water engineer to be fully informed on the principles underlying this most recent system of water purification.

HISTORICAL

The treatment of water by artificial light sources for the purpose of destroying its germ life dates back to Downs and Blunt (1878). They found that the shorter the wave lengths of the light the better the bactericidal action; and they were corroborated in this later on by Duclaux, Arloing, Roux, Geissler and others. We owe to Duclaux the theory that sunlight is the most common and cheapest disinfectant known.

Marshall Ward (1892) completed these important studies by analyzing the effect of arc spectra thrown on infected agar plates; wherever they were struck by violet and particularly by ultra-violet rays they were disinfected and did not develop colonies. This English scientist sterilized Thames water by placing it in a tank equipped with a quartz window and submitting it to the rays of an arc lamp. This was proposed again later on by Lambert.

The first complete analysis of this bactericidal phenomenon of strong light sources we owe to Finsen, who in his famous light healing establishment laid the foundation of our modern knowledge of the action of light on germ life. As you will remember the practical results of this work was the introduction of the light treatment of

[1]Paper read before the American Water Works Association Annual Convention, Philadelphia, May, 1914.

certain diseases by the Finsen lamp. We had, however, to await the arrival of really powerful sources of ultra-violet rays before applying light practically as a bactericidal agent for the purification of water.

This new source of ultra-violet rays was the mercury arc lamp built out of quartz. This mercury arc owes its origin to the work of Mr. Peter Cooper Hewitt, resulting in the well known Cooper Hewitt illuminating lamps. When the ordinary glass of these lamps is replaced by quartz glass, that is to say, fused rock crystal, we obtain a container which allows the greatest amount of the ultra-violet rays produced by the mercury arc to be sent out from the lamp.

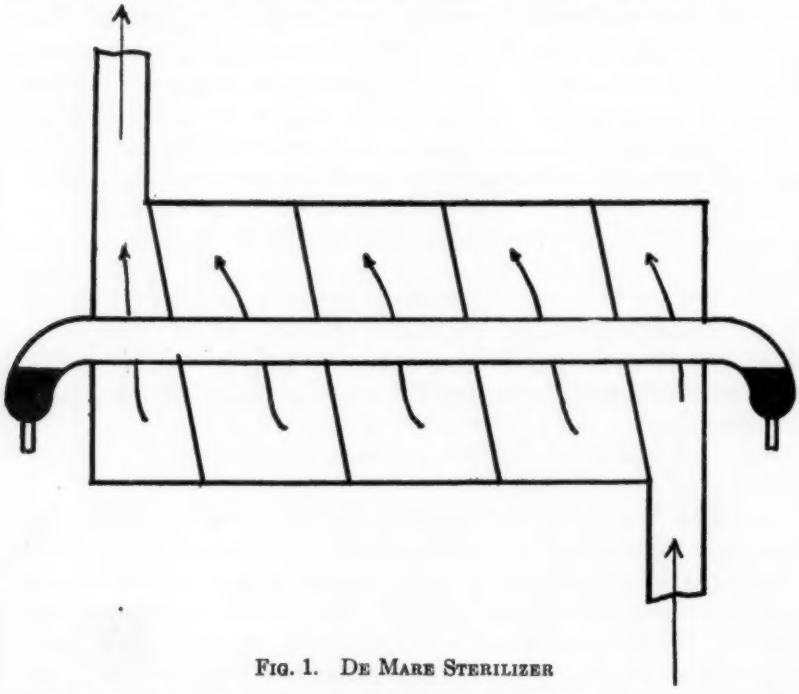


FIG. 1. DE MARE STERILIZER

The first to propose the adoption of the mercury arc for the purification of water was De Mare. His sterilizer consisted of a lamp around which the water flows in a circular path (Fig. 1). Some years later, and nearly simultaneously, different ways of constructing water sterilizers with mercury lamps were tried out by Courmont and Nogier, The Quartz Lampen-Gesellschaft, Billon Daguerre, Vallet, and chiefly by Henri, Helbronner, and von Recklinghausen. The work of the last three named was done at the Sorbonne Univer-

sity in Paris and was particularly elaborate in scientific research as well as practical application. This work has resulted in the installation of several large and very many small ultra-violet ray water purifiers and the writer considers it of interest to show you the development of the principles which took place during the long period of our preparatory work and the introduction of this system into actual practice.

Before going into the details of this work will mention the principle underlying the method of water purification by ultra-violet rays. We know from experiments repeated over and over again, that germs exposed directly to and at a very short distance ($\frac{1}{2}$ to 1 inch) from a powerful source of ultra-violet rays such as we use in a modern sterilizer are killed within a small fraction of a second; in some cases one-twentieth of a second being sufficient.

The principle of the ultra-violet ray water sterilizer is therefore very simple: All we have to do is to lead the water at proper speed through a zone which is illuminated by a lamp which produces a light which is very rich in ultra-violet rays. Every microbe that gets under sufficient influence of the rays during the passage of the water through this illuminated zone is annihilated. We therefore have to attend to two things: first, to an economic illumination of water with ultra-violet rays and second, to make sure that every microbe contained in the water will be really led through the illuminated zone.

If we consider the latter point first we come immediately to the conclusion that nothing must be in the water to intercept the rays, that is to say, there must not be any suspended matter in the water in the shadow of which the germ would be protected from the rays emitted by the lamp. It is therefore imperative that the water be clear. The best way to examine this is to look at the water under a strong light against a dark background. We shall later come back to this point of clearness of the water, as it is of great importance for the economy of the system.

SOURCE OF ULTRA-VIOLET LIGHT

Practically every source of light emits some invisible ultra-violet rays together with the visible rays. This can be studied by dissolving the light into its components by means of a quartz glass prism. Our human eye will see on such a spectrum only the well known colors of the rainbow. It will not see the wave lengths below

the red nor the wave lengths beyond the violet; however, the latter can be easily demonstrated by certain properties they have, for example, certain dye stuffs show a fluorescent color when struck by the ultra-violet rays, also many chemical and physical reactions will take place under the influence of these ultra-violet rays and prove their presence in the spectrum thereby.

The artificial sources of light which are richest in ultra-violet rays are the electric arcs between metal electrodes, for instance, the iron arc, mercury arc, etc. All such arcing between metals is accompanied by disintegration of the metals themselves, therefore the electrodes have to be renewed from time to time. In the case of mercury this renewing can be done in the simplest and easiest manner, namely, by condensing the mercury escaping from the arc and leading the so condensed mercury back to the electrode container. Of course, the arc in this case has to be enclosed hermetically in a container so as to avoid loss of mercury. The material we choose for making this container must be such a quality that the desirable rays are not held up thereby, but on the contrary are allowed to escape freely. This material for the arc container is fused rock crystal or more properly expressed, fused quartz.

For a given amount of electrical energy, put into this arc, such a quartz arc lamp will attain a certain temperature, depending upon its radiating capacity, that is to say on its shape and surroundings. We have found that the amount of ultra-violet rays produced by such a quartz lamp is considerably more when running at a high temperature, than when it is run at a low temperature. The production of ultra-violet rays is therefore the more economical the higher the temperature of the lamp. This high temperature is obtained by raising the voltage of the lamp (fig. 4). We are, however, limited to a certain temperature, namely about 800°C., by the fact that quartz if maintained for a long time at a higher temperature will devitrify becoming thereby more or less opaque to the visible and invisible rays emitted from the arc. As in a water sterilizer we naturally want to approach the lamp as close as possible to the water, we must be careful to consider what has just been said about temperature and prevent the water from cooling the luminous part, rendering it thereby inefficient in its production of ultra-violet rays.

PHYSICAL CHARACTERISTICS OF ULTRA-VIOLET LIGHT

The ether vibrations can be distributed in four groups according to their wave lengths, namely, (1) the electric rays, (2) the infra-red rays, (3) the rays of the visible spectrum, (4) the ultra-violet rays.

Between the last electric rays and the first infra-red rays exists probably a group of still unknown qualities. All these rays travel at the same speed namely, 300,000 kilometers per second. The wave lengths are as follows:

1. Electric waves (Hertz 1888) from several kilometers down to 3 mm.
2. Infra-red rays (Herschel, 1800) from 300 down to 0.76μ.[1]
3. Visible rays (Newton, 1666) from 0.76μ down to 0.40μ.
4. Ultra-violet rays (Ritter, 1802) from 0.40μ down to 0.10μ.

We are interested today in that last named group, number 4, namely the ultra-violet rays whose upper limit is more or less vague (fig. 2). It is sometimes placed at 0.3969μ, however even shorter waves can be

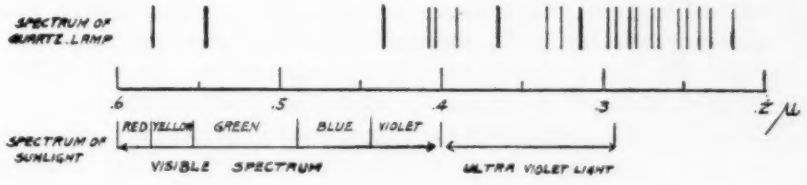


FIG. 2 SPECTRUM OF QUARTZ LAMP AND OF SUNLIGHT

noticed by the eye, although not directly but only by the fact that the crystalline in our eyes becomes fluorescent giving thereby impression of gray on the retina. If people therefore have sometimes thought they were able to see ultra-violet rays they really only saw their own crystalline. The lower limit of 0.10μ of the ultra-violet rays was obtained by Schumann and Lyman by working in vacuum with fluorspar prisms. However, these very short wave lengths do not come into consideration in our case, because a few millimeters of air absorb completely the wave lengths below 0.150μ and several centimeters of air absorb the wave lengths below 0.1850μ. Several kilometers of air absorb the ultra-violet from 0.2943μ down. This wave length is therefore the shortest of the sun's waves reaching our eye,

[1] $\mu = \frac{1}{1000}$ millimeter = 10,000 Angström units.

and therefore the ultra-violet contained in the sun's rays are only the wave lengths between 0.40μ and 0.2943μ.

Quartz the only material which we can apply for our lamps absorbs practically everything below 0.20μ; therefore we may say that from the ultra-violet ray efficiency point of view it does not matter very much whether a quartz lamp is surrounded by a thin layer of air or by vacuum. Glass absorbs ultra-violet rays to an enormous extent as may be seen from the fact that the bactericidal power of a quartz lamp is cut down to $\frac{1}{1000}$ if the lamp is surrounded by a glass tube.

BACTERICIDAL POWER OF ULTRA-VIOLET RAYS

It was of interest to see whether different microbes had different resistivities against ultra-violet rays in the same way that they are different against disinfectants and heat. We come to the astonishing result that they do not vary anything like as much in their resistivity against ultra-violet light as they vary in their resistivity against heat and disinfectants. For instance, spores are often twenty times as resistant as the unprotected forms of germs against chemicals. We find that some are only 1.5 to 5 times as resistant against ultra-violet light as ordinarily unprotected water bacteria. The following table (fig. 3) shows a comparison of different types of germs in their resistivity. In each case under similar conditions cultures were made and the free germs put in clear water, care being taken however to avoid clumps of bacteria and also to avoid the presence of the nourishing medium, for otherwise the germs would have been protected more or less against the rays.

It has sometimes been thought that the bactericidal action of the ultra-violet rays was due to a small amount of hydrogen peroxide which indeed forms itself by the exposure of water to the ultra-violet rays. However, this formation is so minute that it is barely noticeable after ten hours exposure of the water and we can surely say that the bactericidal effect is not due to the action of the so-formed disinfectant, but is a specific typical action of the ultra-violet rays on the germ. It is not likely that by the action of the rays during such a short period, the entire bacteria should be chemically changed, coagulated, or otherwise modified, but it is more probable that some ferment or similar product contained in the cell is modified by the rays and thereby poisons the system of the cell.

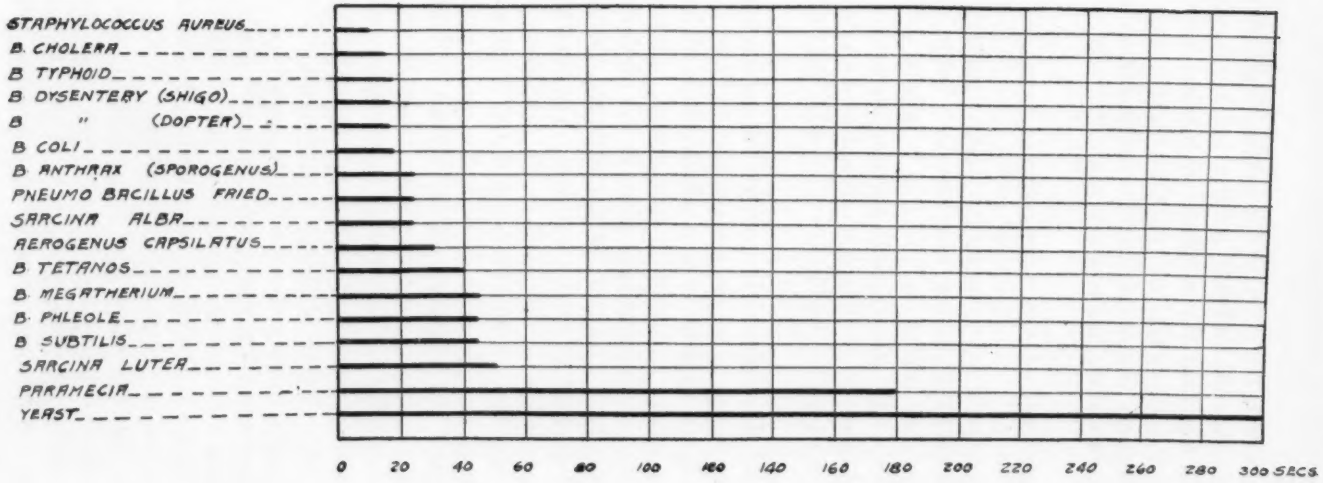


FIG. 3. SECONDS NECESSARY TO KILL DIFFERENT TYPES OF GERMS AT 200 MILLIMETERS FROM A QUARTZ LAMP BURNING AT 66 VOLTS, 3.5 AMPERES

We have often been asked whether the germs struck by the light may not be simply stunned and may survive again afterwards. In answer to this will say that the methods of making the counts in Europe would enable one to find out whether there is any reviving. These counts extended over a period of usually fifteen days and never have shown any indication of revival.

QUANTITOMETRY OF ULTRA-VIOLET RAYS

The luminous power of light sources is usually measured by comparing them with standard lamps, such standard lamps being produced by burning some well-defined fuel in a certain defined way. The moment that the light one wants to measure has a color different from the standard lamp, great difficulties arise, based on the fact that we do not really compare the two lamps physically but only physiologically.

The difficulty of determining the *ultra-violet* candle power of a lamp is far greater again, as we are not sensible to these rays at all. To get some idea of the strength of ultra-violet source we have therefore to create new means and units of comparison. Many different chemicals and physical reactions take place in the ultra-violet light. One may, therefore, base a measure of the ultra-violet candle power on the speed and strength of such a reaction. The most typical and most convenient reaction of this kind is the blackening of photographic paper. We have found that a mercury quartz lamp will blacken paper about four times as quick as the same lamp screened behind a glass plate. An ordinary sensitometer can be built embodying this principle. Another reaction of the ultra-violet rays may be considered by comparing the amount of fluorescence produced by the lamps, but both of these methods of measuring will only allow us to compare light sources of similar composition. They do not give us what is really most interesting for us, namely, a measure of the *bactericidal power* of a lamp, and we therefore thought it best to adopt a real biologic test for the measure of the abiotic strength of quartz lamps. While in the above cases we could easily determine the standard of black or the standard of fluorescence it is impossible to define in the last-mentioned case the standard of bactericidal action. There remains, therefore, nothing for us to do but to establish a standard source of ultra-violet, that is to say, a laboratory standard composed of a certain lamp which is so kept that it is most

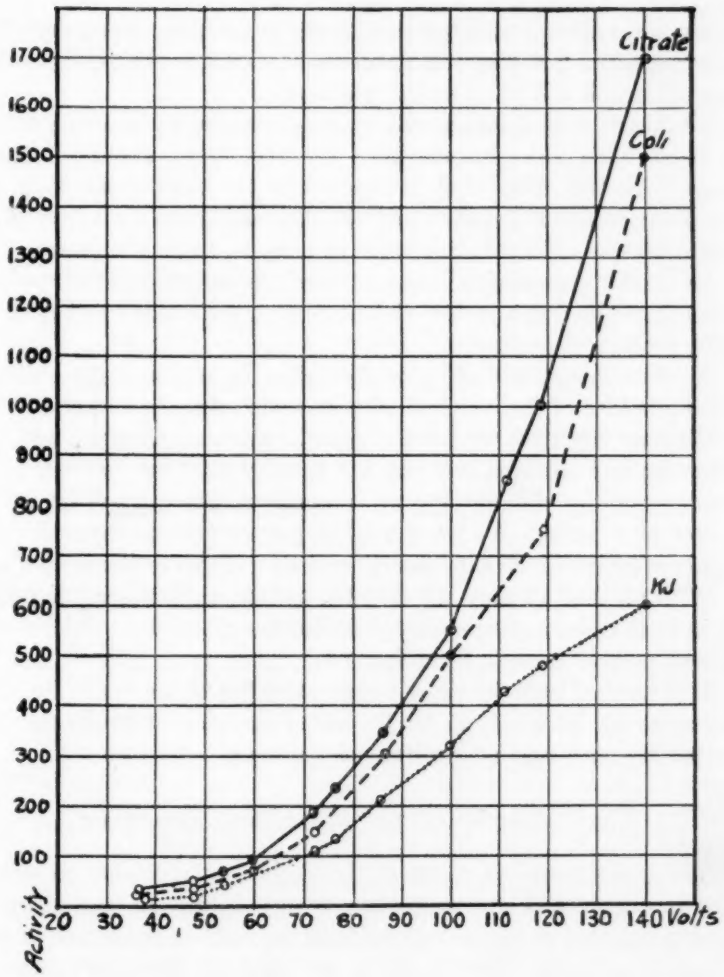


FIG. 4 COMPARATIVE MEASURE OF ULTRA-VIOLET ACTIVITY OF 220 VOLT QUARTZ LAMP BURNING AT DIFFERENT VOLTAGES BY THREE METHODS:

a. Decomposition of Citrate of Silver
b. Decomposition of Potassium Iodide
c. Anihilation of Bacterium Coli

unlikely to change the candle power and compare the action of this lamp with the action of the lamp one wants to measure on one and the same culture of germs. The way we proceed for this process is as follows: we make a culture of paramecias which are very similar in their sensitivity to ultra-violet rays as ordinary water bacteria. As a matter of fact they will stand about six times the exposure that bacterium coli will stand as figure 3 shows.

The sensitivity of such a culture is determined by exposing a drop of it at a defined distance from the laboratory standard quartz lamp. Another drop of it is exposed at the same distance to the lamp one wants to measure and the time necessary for killing gives the indication of the relative value of ultra-violet candle power. We have chosen paramecias because they are easily observed under a microscope, having a rather violent motion while alive and naturally no motion when dead.

A few observations will therefore give us within a few minutes a definite idea of the bactericidal power one wants to measure.

We may say that we have checked figures so obtained with the effect on coli cultures and can see thereby that we have a fairly safe process for determining by comparison, the ultra-violet candle power of a lamp. We have used it particularly to determine the power of lamps which had been in service for longer or shorter periods.

With all that we may say that the action on photographic papers is, in most cases, a precise enough indication of the ultra-violet candle power, as may be seen from figure 4.

It is natural that the electric characteristics of the lamps for these measures are checked up by the usual electrical instruments indicating the amperage and voltage of the lamp.

DEVELOPMENT OF THE STERILIZING APPARATUS

The experiments we made at the Sorbonne laboratory as well as the experiments of others working in this field were started by exposing polluted water in containers to the light of the quartz lamps. These experiments allowed us to get data for the construction of sterilizing apparatus where the water was circulating continually through the illuminated zone.

As examples, for the simplest form of apparatus, will mention the sterilizing tank which we used in our preliminary experiments (fig. 5), and Nogier (fig. 6) and the Quartz lampen Gesellschaft (fig. 7). In

all of these experiments the water was simply passed in a straight flow underneath or around the source of the ultra-violet light. We found the results with this type of apparatus to be irregular and came to the conclusion that this was due to the fact that the water, although clear, still contained some microscopic suspended matter

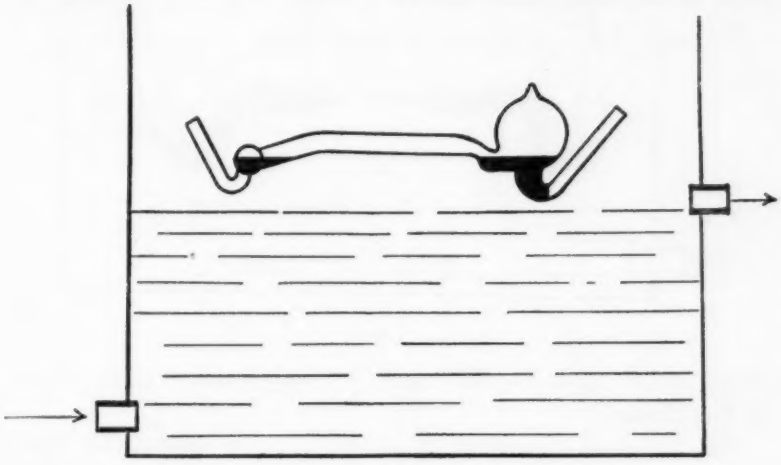


FIG. 5

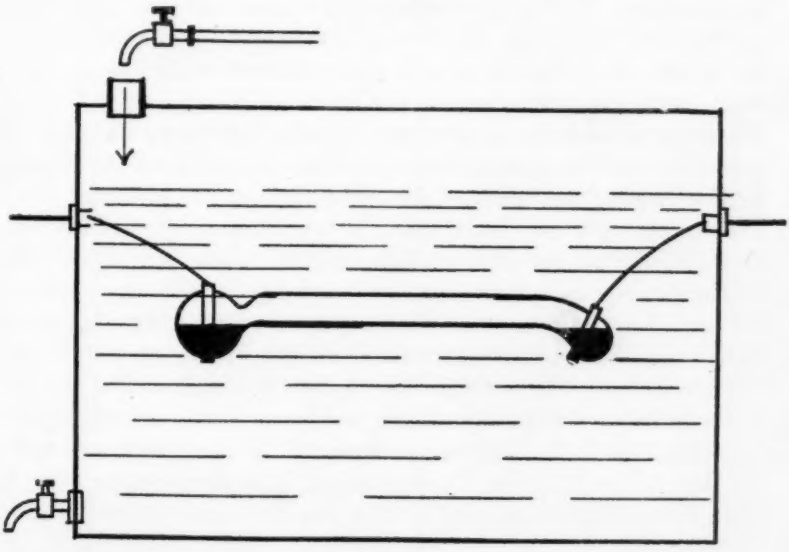


FIG. 6

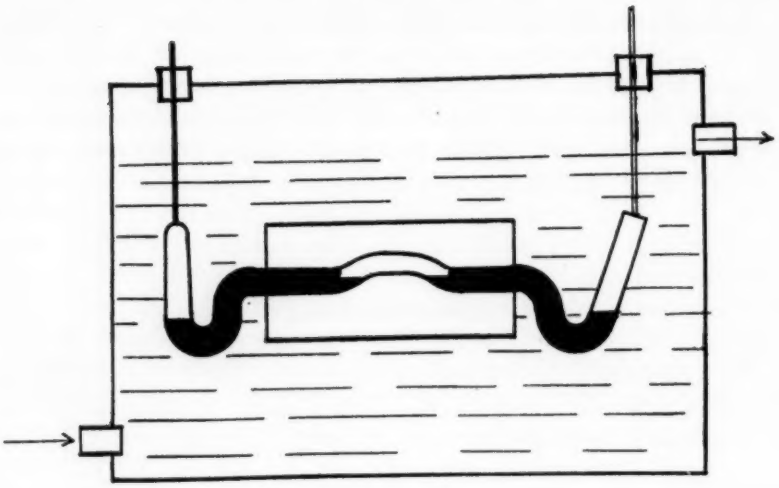


FIG. 7

which when the water was flowing straight would allow microbes to be shielded.

We, therefore, considered it advantageous to expose the water a second and third time to the light after having stirred it between illuminations. In this way we expected to turn over such microscopic particles and have them therefore exposed on all sides to the action of the lamps. A typical case of such apparatus was used by us in experiments at the Sorbonne and is shown in the design figures 8 and 9. The water in a similar apparatus of considerably larger size (fig. 10) flowed through four illuminated zones and stirred itself up through its flow around the bends of the canal between the luminous zones. The results were very satisfactory as we obtained sterilization from about 5000 germs per cubic centimeter down to less than 10 per cubic centimeter, the consumption of electric energy for the lamps being at the rate of 144 kw. hours per million gallons. The submitting of the water to successive illuminations and stirring up during illumination can also be done with a single lamp by so arranging baffles that the water is led several times towards and away from the source of the light (figs. 8 and 9). Typical apparatus of this kind is shown in the B2 (fig. 11) and C3 (fig. 12) apparatus. The former apparatus, B2 type, uses only perhaps one-fourth of the light emitted by the lamp. However the apparatus is easy to handle and of a small size.

The C3 apparatus was constructed in a somewhat different way,

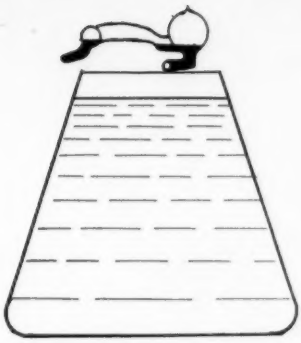


FIG. 8

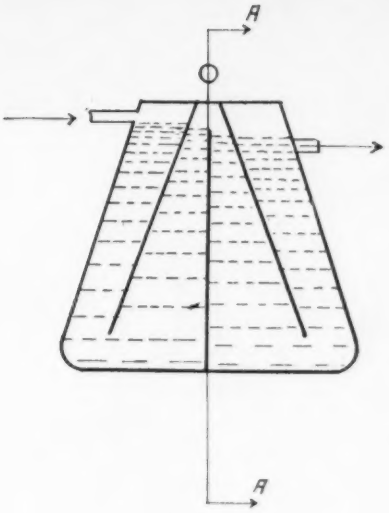
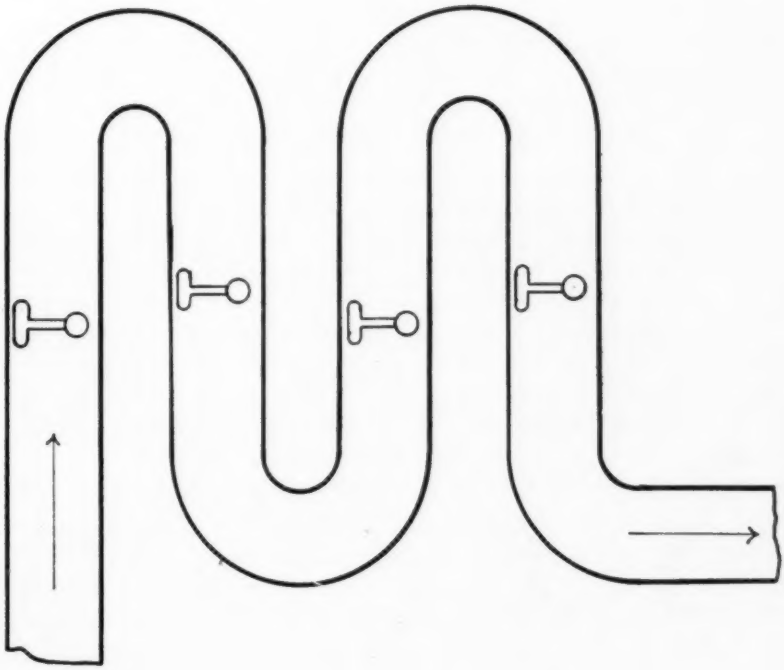


FIG. 9



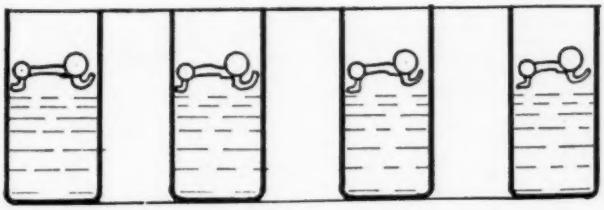


FIG. 10

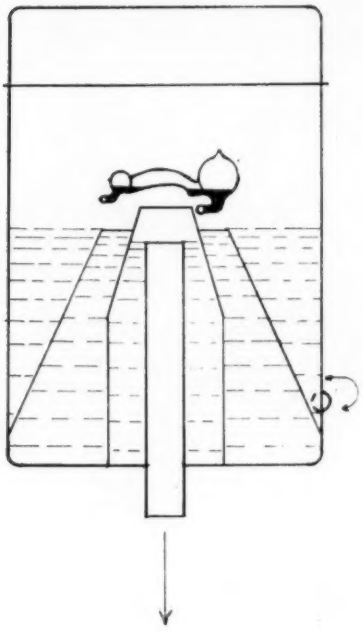


FIG. 11

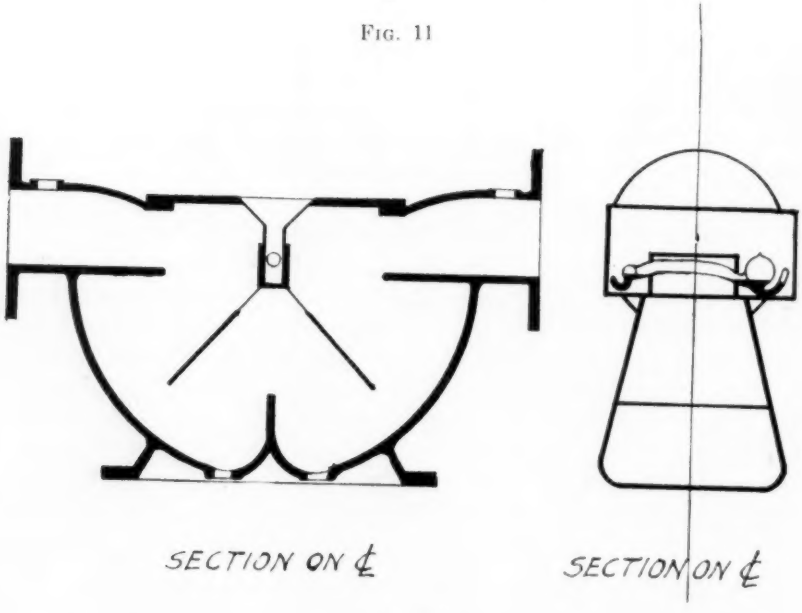


FIG. 12

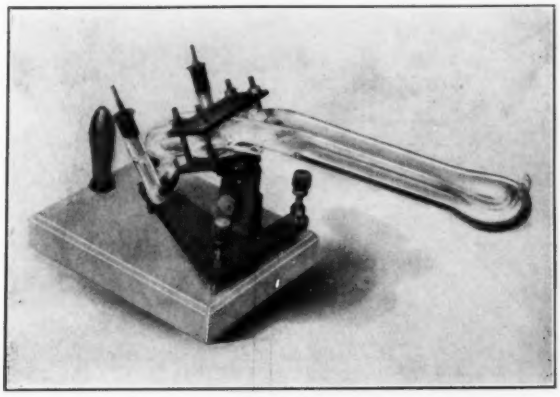


FIG. 13

with a view of using a greater proportion of ultra-violet. The lamp was protected from contact with the water by inserting it into a chamber fitted with quartz windows which chamber was submerged in the tank containing the water. Three contacts of the water with the light are obtained in this apparatus.

It was desired to so construct the lamps that practically all their light could enter into the water and exert its sterilizing action. The so-called pistol lamps which have a U-shaped luminous tube (fig. 13) allow this to be realized, the luminous part being inserted into quartz tubes which protect them from contact with the water (figs. 14 and 15). Such pistol lamp equipments can be inserted into flumes through which the water flows and give the water several successive illuminations (figs. 14, 15). The necessary stirring action in the water is obtained by baffle plates placed in the lamp axis whereby fairly violent stirring is taking place near the lamp.

The largest lamp unit made so far is the 500 volt 2.5 amperes, pistol lamp and a maximum number of ten such lamps are inserted into one single flume.

As to the depth of water in sterilizing apparatus, theoretically the best will be a very great depth of the water. We have observed strong bactericidal action even through three feet of water, the ratio being practically as may be expected inversely as the square of the distance, that is to say for instance, one-ninth of bactericidal action at three times the distance. Calculation and practice have shown us that it is good to provide, if possible, 2 feet depth of water in

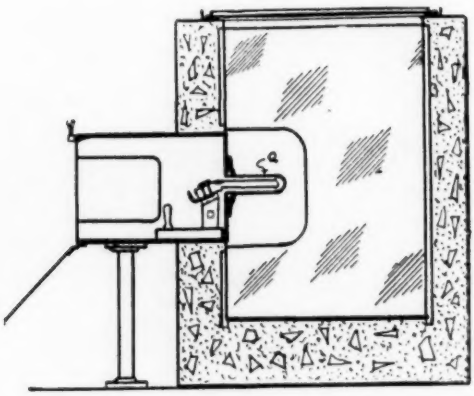


FIG. 14

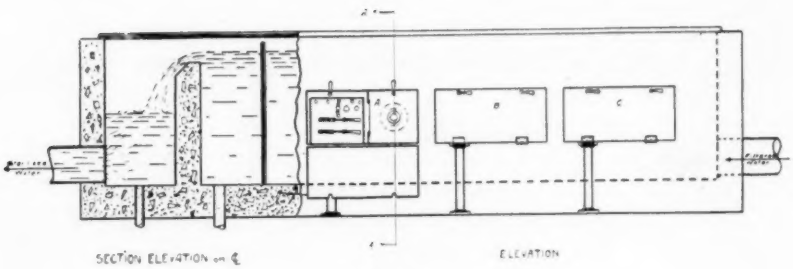


FIG. 15

larger apparatus. Of course in apparatus working with water which is highly colored, this depth may be reduced as otherwise it would make the apparatus unnecessarily cumbersome.

INSTALLATIONS

The whole system having been developed abroad it is only natural that there are considerably more such installations in Europe than in this country. Small installations are used for producing water for drinking and surgical purposes in hospitals, schools, etc., also for bottling purposes. The first large installation of a C3 apparatus (rate of 150,000 gallons per day) has been running since November, 1910, in a suburb of Rouen. The hygienic results from this plant are very satisfactory, typhoid in the district fed with the water from

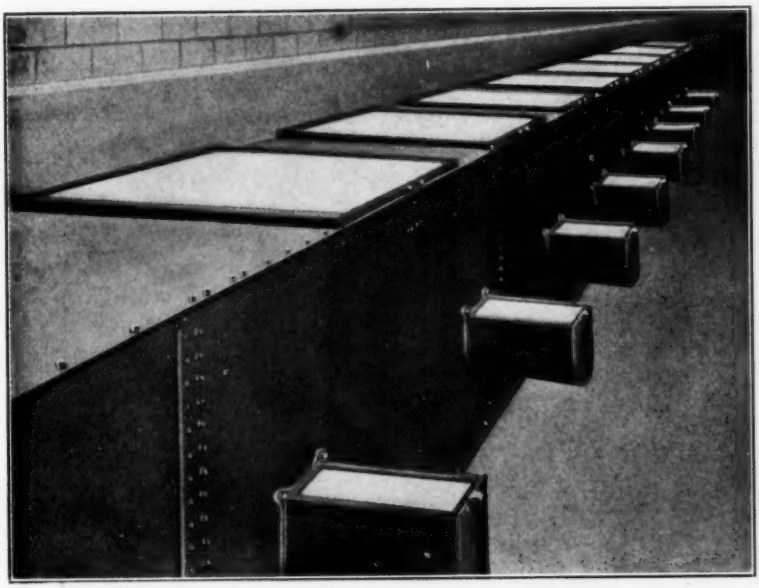


FIG. 16

this plant being extinct whilst it exists still in the surrounding districts which use similar water without ultra-violet ray purification.

A plant with four 220-volt pistol lamps has been running for over a year in Saint Malo sterilizing the water at a rate of 750,000 gallons per twenty-four hours.

Many C3 apparatus are running in France in some cases two being run in series with always very gratifying results. The largest sterilizing unit composed of a flume with ten 500-volt pistol lamps is sterilizing the water for the city of Luneville, France (fig. 16). This supply consists of 1,500,000 gallons of river water and 375,000 gallons of spring water. The water in this case, which in its raw state is extremely muddy and rich in colloidal matter, is filtered through a rough and slow sand filter without the addition of coagulants, at a rate of about 7,000,000 gallons per acre. In case of a biological filtration this type of water would have to be filtered at the rate of 2,500,000 gallons per acre.

The raw water contains countless germs like any heavily polluted river. After filtration it contains at times as many as 1000 germs per cubic centimeter. The water leaves the sterilizer with rarely more

than 10 germs per cubic centimeter, and no coli bacteria, although the water before sterilizing nearly always shows positive coli reaction. Even more gratifying is the hygienic result as may be seen from the following statistics of typhoid mortality in this city; showing the number of cases:

Year	*Jan.* *Feb.* *Mar.*	*Apr.* *May* *June*	*July* *Aug.* *Sept.*	*Oct.* *Nov.* *Dec.*
1908	15	6	121	20
1909	57	12	7	55
1910	19	3	5	46
1911	69	5	32	10
1912	14	11	9*	2
1913	2	5	3	5
1914	0			

* Start of Ultra-Violet Ray Plant

On account of some turbidity, and also an often deep color of the filtered water (up to 40 U. S. standard) this plant has an exceedingly high current consumption, namely, 130 kw. hours per million gallons; during most of the time two-thirds of this consumption would be ample.

The first application of the ultra-violet ray system for sterilizing water on a large scale in this country was started some weeks ago in New York, where the water of a swimming pool is continually being circulated through a rapid filter and a sterilizer flume, equipped with two 220-volt pistol lamps, the flow being about 5000 gallons an hour.

PRELIMINARY CONDITION OF THE WATER BEFORE TREATMENT WITH THE ULTRA-VIOLET RAYS

As mentioned in the theoretical part the ultra-violet rays must be able to strike the microbe; where any suspended matter is interposed the bactericidal action cannot take place, because the microbe is in the shadow. It is certain therefore that only clear water can be submitted to the ultra-violet ray treatment for its sterilization. That is to say in most cases it is necessary to filter the water before the same is submitted to the action of the lamps. As color in solution will absorb ultra-violet rays to a certain extent, it is evidently better to also free the water from coloring material before submitting it to the rays. Nevertheless we have treated water like the above mentioned Luneville waters showing up to about 40 U. S. standard

in color. It is certain in such cases more illumination is necessary than with water having no coloring matter in solution.

The question of suspended matter, in the water, is of somewhat greater importance. Sometimes water with little suspended matter may be more difficult to sterilize than water with far more suspended matter. The reason for this is that it will depend not only on the size and quantity of the suspended matter but also on its biological quality. That is to say suspensions of purely mineral nature which do not enclose any microbes and to which few microbes are attached handicap the sterilization of the water very much less than suspended particles in similar water which are heavily covered with microbes and particularly so if microbes are enclosed in these particles, because it is then most likely that a repeated exposure to the rays will be necessary to penetrate to the enclosed germ life.

If the suspended matter is of smaller size than the germs like colloidal clay we expect such turbidity to act more or less like color in solution, demanding simply more illumination than clear water. Experiments made with one of the B2 apparatus on water showing up to 20 turbidity seem to prove that such fine turbidity does not handicap sterilization very much.

From the economical point of view the condition in which the water is submitted to the rays is evidently of great importance for the ultra-violet rays sterilization system. Physically ideal water, that is to say, water without suspended matter, turbidity or color will need very little power in ultra-violet ray to become sterile. In large plants 50 kw. hours per million gallons will produce a great *over-dose* in ultra-violet and it will always be more economical to adopt the filtering system which gives the physically best results because it will also be the most economical in its demand of ultra-violet ray treatment.

Smaller installations are being equipped usually with charcoal or paper filters. In large plants naturally the filter question is an engineering proposition; so is the question of choice between mechanical and sand filter.

It seems that if the latter are chosen they can be speeded up to a great extent as against the speed for biological filtration and still give a physically pure enough water for ultra-violet ray treatment, as for example the Luneville plant where the water is filtered practically at three times the rate of biological filtration for that particular kind of water. In other plants the filtration has been speeded up to 10,000,000 gallons, to 12,000,000 gallons per acre and we even tried

with fair success 25,000,000 gallons per acre followed by ultra-violet ray treatment. This will naturally always depend on the filtrability of the water.

OPERATING COSTS

Operating costs will vary with the size and the running hours of the plant, and the *coefficient of safety* one wants to give to the ultra-violet ray treatment. According to the quality of the water, in large plants the current consumption will vary between 50 and 125 kw. hours per million gallons allowing for a large safety coefficient. The labor charges are negligible as the apparatus only needs an occasional cleaning and starting of lamps. Apart from this the lamps have to be repumped and repaired from time to time. When the water is of variable physical quality, one will have so to establish the plant that all the lamps will be running during the period of least transparent water and only some of them during the period of best transparency.

In any engineering proposition we always try to adopt as large a *safety coefficient* as possible. It we rely merely on chemicals to disinfect our water, we must work right close to and sometimes even over the limit of the amount which will not make itself objectionable by producing taste and odor in the water.

There is an increasing opposition to the use of chemicals for the purification of water supplies except as a makeshift as we may see from the remarks made by Mr. George A. Johnson, in the *Journal of the American Public Health Association*, (Aug., 1911) where he mentions the great difficulty of avoiding under-dosing or over-dosing. Mr. Allen Hazen speaks even of the "Difficulty or sometimes the impossibility of disinfecting waters with hypochlorite of lime without at the same time producing disagreeable tastes or odors."

In the ultra-violet rays we have a system where we may choose *our safety coefficient as high as ever we liked*, that is to say, we may *over-dose* our sterilization as much as we want without creating any objectionable features in the water, like taste and odor. The waterworks engineer has therefore in this system a much more satisfactory weapon against pollution than he ever had before.

DISCUSSION

MR. F. A. DALLYN: The Association is to be congratulated upon obtaining this paper from Dr. von Recklinghausen. He has been very modest indeed in his claims for the ultra-violet rays. He has certainly given us a most scientific paper upon the working of the system. In the experimental station attached to the provincial board of health, Ontario, a very small unit, type B2, has been tested. The speaker is very much of the opinion that we have just had the first word upon the ultra-violet ray for water sterilization (using the word "sterilization" advisedly) and that we will hear more of it as time goes on. The cost appears to be only about three times that arising out of the use of ordinary disinfecting agents. No doubt, public opinion will demand its use just as soon as its merits are clearly before the minds of the people.

MR. SHEPPARD T. POWELL: Some time ago the speaker did some work with ultra-violet rays, employing the apparatus which Dr. von Recklinghausen has described in his paper, figure 11, namely, the small domestic sterilizer. We got it about two and a half years ago direct from London. In this work we used Baltimore city water. This was before we had sterilization by hypochlorite of lime.

Before applying this method the total bacterial count ran from a few hundred to several thousand, but by the use of the sterilizer, although the time of contact was very short, we found almost absolute sterility of the water resulted. The main thing that the speaker thinks this Association should consider in ultra-violet ray sterilization is the question of cost. Dr. von Recklinghausen reports an average K. W. consumption of 30 to 125. Now if we place that average at say 75, and put the cost at 2 cents per K. W.; which most of you will agree is low enough except in a hydro-electric proposition, we have a K. W. consumption cost alone of $1.50. To this must be added the depreciation and interest on investment which will make a very considerable cost, especially when you consider that this is merely for the sterilization of the water exclusive of filtration. It is not so much the question of the efficiency of the ultra-violet ray as a bacteriacidal agent as it is the question of what it is going to cost. Of course the liquid chlorine method is becoming more and more popular, so that these lamps will have to be very much reduced in cost and something done to bring them into such

condition that they will not have to be re-pumped so often, before the ultra-violet rays will be a practical method of water purification.

MR. B. F. SHAW: The speaker was interested in the statement in the paper of the success attained at Luneville with water containing a rather high amount of color. Several years ago he did a small amount of work with the mercury arc lamp, working with Boston tap water which had a moderate amount of color, about 4 U. S. Standard. He found that the absorption appeared to be practically complete even in so short a distance as 20 cm. There appeared to be no bacteriacidal effect at that distance with water of that color, and would like to ask if Dr. von Recklinghausen will state whether the results obtained in measuring the effect of the lamp on the bacterial culture, by means of the time taken to kill the bacteria present, are consistent in a number of cases using the same source of light and the same culture? The speaker never attempted anything of that character himself, but the work that has been published by Professor Phelps of Boston and Mr. Chick of England, and others, on the character of curve of disinfection, and its resemblance to the logarithmic curve, would seem to indicate a priori that the time of disinfection would be a quantity difficult to determine closely, and rather unsatisfactory as a measure of the ability of the lamp to disinfect.

DR. MAX VON RECKLINGHAUSEN: The first question asked was in reference to the cost. Mr. Powell is quite right that the cost is somewhat higher than the mere use of chemicals, especially when one considers that the lamps will need repairs and repumping after a certain time. The speaker has often had that experience with lamps used in the laboratory, and not in continuous service. They suffered much more than lamps which are started once by the operator and are then left burning for days and months. If the lamps are handled frequently as is the case in testing in the laboratory they will suffer infinitely more than when in continuous, regular and quiet service. There is no doubt that a laboratory lamp needs perhaps, ten times as much repairing as a lamp which is put in service in a plant and left burning. The depreciation of lamps is evidently a cost factor but do not think that it should run very high. Of course, the speaker does not want to give any commercial figures but he knows that the lamp makers themselves are willing to stand back of the lamps.

Now let us say that the ultra-violet ray treatment does cost more than the treatment with hypochlorite or treatment with chlorine, is there not a great advantage in the possibility of *overdosing* a sterilizing agent to an enormous extent without having any secondary reaction going along with it, that is to say without producing *bad* water? What are we after? We want to produce good water. Good water should evidently taste good too, and should always taste good. If we use chemicals we may be able to often keep below the limit of taste and odor and get practically sterile water but is it not better to *over-do* the sterilization to a great extent and be sure that you never get *any* taste. This matter really ought not to be measured upon the basis of dollars and cents alone.

On the other hand, handling chemicals such as hypochlorite and particularly liquid chlorine is not only disagreeable but even dangerous. There is no doubt about that, and you have to protect your operators against injuries from these chemicals.

Another thing mentioned when speaking about the relative resistivities of different types of germs is that the spores are not very much more resistant against ultra-violet than ordinary water bacteria. This is very important as some spores are pathogenic. Contrary to chemicals the ultra-violet rays act practically as well on spores as they do on ordinary water bacteria, and, therefore, sterilizing the water with ultra-violet rays creates a much *safer water*, and the slogan here in this country is always "safety first."

As to the results mentioned when exposing Boston tap water of the color 4, the speaker believes that these experiments were made without observing all necessary precautions; though of course, he can not trace this particular case in detail, he has been able to trace most cases of irregular results down to the presence of a certain amount of suspended matter. He personally has never worked with Boston water. Of course, it may be beautifully filtered at the water works but whether it gets in the same condition to the tap, he does not know. So that in the tests there might have been some growth introduced from the inside of the pipes into the water which was being tested, which protected some of the germs contained in the water from the action of the lamp.

Some years' experience with the ultra-violet rays have given the speaker the feeling of having an absolutely safe sterilizing agent. There is nothing mysterious about them, and if one follows the rule of taking water without suspended matter of any kind one will

always get the same regular sterilizing results. We have often found a total absence of bacteria in 40 cc. even when working with water having up to 40 U. S. standard color. Therefore the tests on Boston tap water with only 4 in color must have been made under unfavorable conditions.

As to the consistency of the figures on relative resistivity of different germs you are referred to our original publications. To repeat these tests needs very careful work so as to prepare the germ cultures in such a way that they will be as near as possible in a similar physical state. The germs must not be in clumps, but isolated. They must not be imbedded in their medium of culture, but floating freely in the water. If one compares for instance broth cultures directly one will get very uneven results, because the bacteria may be in clumps and besides protected against the light by the colloidal contents of the broth.

THE EFFICIENCY OF HOUSEHOLD FILTERS IN CHICAGO

By Arthur Lederer[1] and Frank Bachmann[2]

The efficiency of household filters has on numerous occasions been studied, mainly, however, with reference to one or the other type of filters. We are not aware of any investigation which has been undertaken in a large city with a view of obtaining information on the quality of household filtered water in general. It was not our intention to study individual types of filters, the pro and con of their construction, or the uniformity of results obtainable at various times. The question before us was: What is the quality of the water obtained from household filters in Chicago at the present time? Such an investigation should necessarily be sufficiently extended to supply data for a fair average, including both efficient and worthless filters, filters cared for intelligently and others totally neglected, some widely advertised and others comparatively unknown. Unless an investigation of this kind is broad enough to cover the examination of a sufficiently large number of filters, one type of filter might possibly prove to be better or worse than it really deserves. In examining about 80 filters, for instance, we have found only one filter of a certain type. This, of course, should not be taken to mean that this particular filter has not been a good seller. Over 1000 filters should be tested in a city of the size of Chicago to learn approximately the ratio of use of various types in households.

There is still another angle to be considered. The more filters of one particular make are examined, the more accurately is it possible to draw conclusions; but even where but one filter of one particular type is examined, certain definite conclusions of negative value can be arrived at. If this single examination of a certain type of filter shows a very low bacterial count in the effluent, or even sterility, it does not mean this particular type should be recommended, unquali-

[1] Chemist and Bacteriologist, the Sanitary District of Chicago.
[2] Assistant Chemist, the Sanitary District of Chicago.

fiedly, without making more frequent tests and a more thorough investigation. On the other hand, if this single test shows a poor effluent from a bacterial standpoint, there is good cause for condemning the filter, since it indicates that at times the filter effluent might not even be as good as the raw water. Of course, it is self-evident that a filter may give poor results not because of faulty construction but because of lack of proper care. This, however, does not necessarily relieve the manufacturer of such product from criticism. Any manufacturer of household filters who has not yet learned this lesson must come to recognize that it is impossible to produce an entirely fool-proof filter and that the most ingenious and scientifically correct types will shipwreck on the human element which enters into the supervision and care required to retain continuous efficiency. Directions are worthless, or practically so, unless they are followed in more than a perfunctory manner.

What should be the function of an ideal household filter? The answer is simple. It should eliminate the turbidity and practically all of the bacteria at all times, without altering the palatability of the supply. It may seem rather severe to require a filter to furnish absolutely sterile water, hence from the standpoint of the sanitarian, the complete removal of gas forming bacteria when tested in 10 cc. of the water should prove satisfactory. Yet our investigation has shown that a certain type of filter will give an average of nearly 100 per cent bacterial removal. There is no reason then why we should not strive to attain a standard which is within our reach.

Various material is employed in the manufacture of these household filters, such as unglazed porcelain or kaolin, diatomaceous earth, natural stone, artificial stone, coal, asbestos, filter paper, etc. The types heretofore valued most highly by the scientific world have been the Pasteur-Chamberland type, in which the water is passed through unglazed porcelain bougies, and the Berkefeld type, which contains bougies of diatomaceous earth. Both of these filters are known to furnish sterile effluents under expert care. Such care, however, cannot be had in the ordinary house. The best filters prove bacteria proof for only a limited time under such conditions. The very fact that the turbidity is removed by most of those household filters, good as well as poor types included, conduces to an unjustified feeling of security. Micro-organisms are much smaller than most suspended matter, even the finely divided clay which constitutes the turbidity of our lake water. It is not surprising that bacteria

pass through the minute pores of filters, even of the Pasteur and Berkefeld types. When first used, the effluent may be sterile, for the reason that these pores are tortuous. Certain bacteria multiply rapidly within the filter material and are finally forced through into the effluent by the water pressure. Still if the bougie or candle, as it is popularly called, is daily boiled or even cleaned two or three times a week, a reasonably safe supply seems assured with filters of that type, unless extreme conditions prevail.

Numerous experiments by others with artificially infected water have shown that B. coli communis, B. typhosus, and B. cholerae fail to pass through the candle, while the ordinary harmless water bacteria do. One observer has succeeded in growing B. typhosus through the walls of a Berkefeld candle. The shortest time for the typhoid bacili to grow through the walls of the candles was found to be four days, and it would therefore seem sufficient to clean and boil the candles twice a week. Of course, the fact that typhoid bacili have been grown through the walls of the candle is more of scientific rather than practical interest, for unusual conditions were established. It makes an enormous difference whether a pure typhoid culture passes through a filter or a polluted water containing a comparatively small number of these disease producing bacteria or a water which is comparatively free from any pollution. It is probable that even when a Berkefeld or Pasteur filter is not cleaned every three to four days, the typhoid bacteria, if present, would be completely eliminated. There is undoubtedly a biologic activity in these filters of which we have little concrete knowledge and which exerts a selective destructive action upon the intestinal group of pathogenic bacteria. It is understood, of course, that these observations apply not only to the Pasteur and Berkefeld filters, but also to the varied types which employ unglazed porcelain or diatomaceous earth for a filter material.

It is remarkable that among the 84 filters examined by us not one Berkefeld filter was found. The objection to the stone filters particularly to the natural stone filters, is that the pores are so large that they permit the accumulation of sediment and the propagation of bacteria, so that the effluent at times actually appears worse than the raw water entering the filter. The closer and finer the pores of a filter, the better the bacterial result. Increasing the rate of filtration implies uncertain results with domestic filters. Any attempt to force filtration by increasing the pressure or by substitut-

ing a more porous filtering material must of necessity be followed by poorer results.

Very often water may be contaminated in the storage reservoir after it has passed through the filter. Undoubtedly this has occurred in a number of cases with the effluents from the Pasteur-Chamberland filters (table I) and others. A construction which eliminates the chance of contamination of the filtered water, like the Red Cross type, is undoubtedly more desirable. As our purpose was to learn the quality of the water delivered to the consumer, the storage reservoir was considered a part of the filter, even if not furnished by the filter manufacturer. It may seem unjust to blame the contamination on the filter manufacturer when the filter alone delivers a safe supply, but the manufacturer must be prepared to shoulder the blame, as long as his filter and appurtenances does not completely eliminate the human element up to the time of actual consumption. In the majority of the filters, a separate storage reservoir is employed, usually a crock, glass bottles, or similar receptacles. The shorter the period of storage in the storage reservoir the less the chance for multiplication of undesirable species of bacteria which may have entered the reservoir through the filter or otherwise.

Our investigation of household filters in Chicago was carried on during January and February, 1914, and naturally was attended with much difficulty. Reliable, intelligent information is often very hard to obtain. The average housekeeper looks upon an investigation of her filter with suspicion, believing it to be a novel scheme to sell her a filter of another type. Often, the investigator is referred to the maid for information on the care of the filter, and in such cases the value of information obtained will be in direct proportion to the intelligence and interest of the informant. Nevertheless, we have endeavored to compile all the data possible on the care which each individual filter examined by us received. The examination of the water entering and leaving the filter was directed towards noting the bacterial and physical improvement. The physical improvement in a water supply like that of Chicago can best be judged by the elimination of the turbidity. The number of bacteria growing on gelatin at 20°C. in three days roughly serves as an index of the harmless types of water bacteria. The number of bacteria growing on litmus lactose agar at 37°C. in two days roughly serves as an index of the intestinal types, although not all of these types actually originate in the intestinal canal. An excessive number

of these bacteria particularly when acid forming colonies are found on the culture plate, may indicate the possibility of sewage contamination. The numerical relation of the bacteria forming at 20°C. and 37°C. should be taken into account. The number of bacteria developing at 20°C. on gelatin may be extremely high, yet if no bacteria or very few develop on agar at 37°C., such high counts have little sanitary significance for they may be due to the rapid multiplication of certain harmless types. The presumptive fermentation test for colon bacili made by incubating various quantities of the water with lactose broth and incubating the mixture in fermentation tubes at 37°C. for two days is of great significance. If fermentation does not take place on inoculation with 10 cc. of the water, the water may be considered to be of good quality. We have not endeavored to test larger quantities of the filtered water for the presence of gas forming bacteria.

Table I shows the result of the investigation obtained with 29 filters of the Pasteur-Chamberland type. The total number of people served by these 29 filters is 316. The average of the results of the examination of the effluents is unduly influenced by filter No. 77. Apparently, the storage reservoir has been contaminated; hence the poor result does not indicate that the filter itself was inefficient. As a matter of fact, a second examination a few weeks later gave results in keeping with the other results obtained with this type. In two of the filters, viz: Nos. 2 and 37, of the Globe Reservoir type, in which the reservoir is directly attached to the middle part containing the candle, the bacterial result is very good, as well as the physical improvement.

In filter No. 14 the care of the filter is reasonably good. The candle is washed once or twice a week and baked once every two weeks, yet the harmless types growing on gelatin are present in larger number in the effluent than in the raw water, although the suspicious species are completely eliminated. The water had been stored in the storage reservoir for some time, hence the increase is undoubtedly the result of multiplication of a few bacteria present at the start. As a rule, the candle will furnish more water in a given time at the beginning than later during service. The reason for this is apparent. The yield will lessen as the porosity of the filter decreases. Exposing the candle to heat, or "baking" it, as it is commonly called, will improve the yield for some time afterwards. Apparently, good bacterial results can be obtained without baking the candle at fre-

quent intervals. The candle in No. 35 has not been baked for the last three years, but merely brushed once a week. Candles No. 41 and 54 have not been baked for the last four years, and there are others which have not been baked for a few years past, yet the bacterial results are highly satisfactory. In filters 2 and 47, the candles are brushed but once a month, and have not been baked for the last ten years, if the information obtained can be relied upon, yet the bacterial efficiency is excellent. It seems to be the general practice to brush the candle once a day or two to three times a week. Apparently the bacterial efficiency is not influenced by the frequency of cleaning, which seems to verify our assumption that the bacteria propagate in the water after it has passed the filter and that the filter as such is doing what it is expected to do. We have not considered the influence of frequency of cleaning on yield, but we have no doubt that there is some.

In the Red Cross type of filter the water is passed through unglazed porcelain. The filtered water is cooled in a small tightly closed reservoir connected with the filter. The filter is not sold outright, but is rented with an inspection service to visit each filter systematically once every month. Table II will show the results obtained with this filter. The number of filters of this type examined was 25, serving 125 people. The record of efficiency of the filter is excellent (table II) demonstrating that an excellent water can be obtained under Chicago conditions from household filters if they are properly constructed and supervised by experts.

The filters of the Chicago Water Purifying Company are likewise rented, with inspection by the concern monthly, but the bacterial results obtained in no way measure up to the results obtained with the Pasteur or Red Cross filters. As a matter of fact, in four out of the seven filter effluents examined, the number of bacteria growing on gelatin was very much higher than in the raw water, and the number of bacteria developed at blood temperature was high in all but two cases. In all but two cases the turbidity was eliminated, however. We did not examine the construction of this filter. The filtered water is passed through a pipe into a coil in the ice chamber of the kitchen refrigerator, to insure a cool supply at all times. This can be drawn either from a faucet underneath the filter or from a faucet on the icebox. We have not examined the efficiency of the filters from the construction standpoint, so we have, therefore, limited our discussion to such details as were self-evident or gathered from

advertising literature. We cannot say, therefore, whether the poor results obtained with this filter are due to the quality of the filtering material or to multiplication of bacteria after filtration. We do know, however, that the results obtained and tabulated in table III are unsatisfactory.

We have also examined five filters of the Everson Filter Company of Chicago. According to their literature, the water passes through artificial stone. In some types of this filter, the water is passed in addition through a metal casing filled with charcoal.

Our data indicate that small amounts of turbidity are removed satisfactorily, but that the bacterial efficiency cannot always be depended upon.

Of the other individual filters (table V), the data collected is not sufficient to warrant a final statement on reliability. However, in interpreting the results contained in table V, we would impress on the reader that he should not place too much confidence in one single result that is favorable, and that he should look with suspicion on any filter not eliminating turbidity and practically all bacteria.

The filters of the Cleveland Stamping and Tool Company and the "Success" type contain natural stone as the filtering material, through which the water filters by gravity into a lower chamber serving as a storage basin. Such filters afford opportunity for the multiplication of bacteria, and do not completely remove the turbidity. This holds true also of the "Superlative Germ Proof" filters, a pressure type of filter, in which the filtering medium consists of one or several discs of filter paper. The filters made by the Bowden Single Valve Filter Company, the International Filter Company (Style C), and the Loomis-Manning Company are large pressure filters, usually supplying several apartments or an entire building. In filters of this type the water is first coagulated with alum and subsequently filtered under pressure through sand or similar material. Among the results in table VI there are few in which the bacteria as well as the turbidity are as completely eliminated as was the case with the smaller Red Cross type.

In fairness both to the user and manufacturer, the types of filters which have shown a perfect or nearly perfect removal of bacteria and turbidity should, however, be tested more thoroughly from a bacterial standpoint than we have been able to do in the time available for the preparation of this paper.

TABLE I

Results Obtained with Pasteur Chamberland Devices

SERIAL NO.	NO. PERSONS SERVED	INFLUENT				EFFLUENT			
		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter	
				L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.			Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.
4	7	30	0	1	20	5	0	0	0
11	5	30	0	4	140	0	0	1	2
14	14	30	1	3	55	5	0	0	140
15	8	30	0	10	100	0	0	0	2
28	6	15	0	2	35	0	0	0	0
34	6	30	3	5	110	5	0	0	20
35	5	20	1	2	80	0	0	0	30
37	5	25	2	5	.....	0	0	0	.....
38	7	20	2	2	.....	0	0	0	.....
39	7	20	0	1	.....	0	0	0	.....
41	12	20	1	4	.....	0	0	0	.....
44	10	15	0	2	.....	0	0	0	.....
45	3	50	1	5	80	0	0	0	3
47	5	80	0	14	230	0	0	0	1
54	5	15	0	1	25	0		0	0
55	3	15	3	1	30	0	0	0	0
59	6	15	0	4	33	0	0	0	0
61	8	25	1	0	30	0	0	1	0
65	6	20	0	0	10	0	0	0	0
66	4	25	1	0	9	0	0	1	0
75	2	70	0	14 (3 acid)	55	0	0	4	0
76	3	70	1	Subtilis growth	160	0	0	0	0
77	150	50	0	12	140	0	0	560	4800
78	6	50	0	10 (1 acid)	30	0	0	0	2
79	3	50	0	12	20	0	0	0	0
2	3	40	0	3	160	0	0	0	0
12	6	40	1	7	38	0	0	0	0
7	3	30	0	2	10	5	0	10	1
16a	8	0	0	0	30	0	0	0	0

16a	8	0	0	0	30	0	0	0	0

TABLE II

Results obtained with Red Cross filters

SERIAL NO.	NO. PERSONS SERVED	INFLUENT				EFFLUENT			
		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter	
				L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.			L. L. Agar, 48 hrs., 20°C.	Gelatin, 72 hrs., 20°C.
13	7	40	0	4	32	5	0	0	0
17	5	20	0	1	15	0	0	0	0
18	4	25	1	1	50	0	0	0	0
19	5	20	0	3	72	0	0	0	0
20	2	30	0	2	18	0	0	0	0
21	6	20	0	0	90	0	0	1	1
29	4	25	1	7 (1 acid)	120	0	0	0	0
30	4	25	0	7 (1 acid)	120	0	0	0	0
42	4	10	1	1	.....	0	0	0	.....
46	6	50	0	8	105	0	0	0	0
49	6	50	0	5	70	0	0	0	2
50	7	30	2	10	70	0	0	0	0
51	5	15	2	1	10	0	0	0	0
52	4	10	0	0	5	0	0	0	0
57	5	15	0	1	6	0	0	0	0
58	6	15	0	3	20	0	0	0	0
70	4	80	3	25 (1 acid)	160	0	0	0	0
71	4	80	1	20 (4 acid)	120	0	0	0	0
72	2	30	0	3	14	0	0	0	0
73	3	30	0	6	14	0	0	0	0
74	7	30	1	6 (2 acid)	18	0	0	0	0
60	6	20	1	0	15	0	0	0	0
62	5	30	0	2	45	0	0	0	0
63	10	20	0	0	18	0	0	0	0
67	4	25	1	1	22	0	0	0	0

TABLE III

Results obtained with filters of the Chicago Water Purifying Company

SERIAL NO.	NO. PERSONS SERVED	INFLUENT				EFFLUENT			
		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter	
				L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.			L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs. 20°C.
22	6	20	0	0	90	0	0	500	13,000
23	5	20	0	0	90	0	0	0	12
24	6	20	0	0	90	0	0	3	4
25	5	25	0	1	48	10	0	2	25
26	6	20	0	0	42	10	0	4	4,000
27	6	15	0	2	35	0	0	4	850
31	4	25	0	3 (1 acid)	75	0	0	0	120

TABLE IV

Results obtained with filters of the Everson Filter Company

SERIAL NO.	NO. PERSONS SERVED	INFLUENT				EFFLUENT			
		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter	
				L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.			L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs. 20°C.
33	5	20	0	2	100	0	0	0	5
43	3	10	1	2	.....	0	0	96	.....
64	6	30	2	0	10	0	0	0	0
68	6	20	1	0	25	0	0	1	0
80	350	50	1	15 (1 acid)	250	0	0	9	10

TABLE V

Results obtained with filters of various other types

SERIAL NO.	NO. PERSONS SERVED	TYPE OF FILTER	INFLUENT				EFFLUENT			
			Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter		Turbidity	Presump. test, B. Coli in 10 cc.	No. bacteria per cubic centimeter	
					L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.			L. L. Agar, 48 hrs., 37°C.	Gelatin, 72 hrs., 20°C.
36	6	Allen Filter Company (a)	20	1	1	.....	0	0	0	.....
48	4	Allen Filter Company (a)	30	0	4	90	0	0	40	Liquefaction
81	8	Allen Filter Company (a)	50	1	6	30	0	0	4	0
1	2	"The Leader"	30	0	8 (1 acid)	60	20	0	1	11
32	4	"The Leader"	25	0	3 (1 acid)	75	0	0	0	220
6	2	"Eclipse" (g)	30	0	3	28	10	0	1	2
56	4	"Eclipse" (g)	15	0	3	10	0	0	0	0
9	6	Cleveland S.&T. Company(b)	20	0	1	15	10	0	2	7500
8	7	Cleveland S.&T. Company(b)	20	0	4	10	5	0	0	10
5	4	The Success Filter (h)	20	0	2	8	10	0	25,000	Liquefaction
10	300	Lynn. Style C–1 (c)	30	1	4	124	5	0	0	0
53	5	Knoble Filter Company (i)	15	3	2	25	0	0	0	0
84	5	Loomis (d)	15	3	1	30	0	0	2	3
83	6	Bowden (j)	15	0	1	25	0	0	0	5
82	5	"Superlative" (e)	40	1	7	440	30	1	8	40
40	30	"Superlative" (e)	20	0	2	.....	5	0	350	.....
16	8	Style C Intern. (k)	10	0	3 (1 acid)	40	0	0	0	30
69	12	Crystal F. F. Company (f)	20	0	0	12	10	0	0	0
3	3	The Dayton (l)	40	0	5	140	5	0	1	0

(a) Allen Germ Proof Filter Co.
(b) Cleveland Stamping & Tool Co.
(c) Lynn Filter Mfg. Co., Style C–1.
(d) Loomis Manning Filter Co.
(e) "Superlative Germ Proof," International Filter Co.
(f) The Crystal Fountain Filter Co., Dayton, O.
(g) The "Eclipse," Hygeia Filter Co., Detroit, Mich.
(h) The Success Filter Mfg. Co., Red Wing, Minn.
(i) Knoble Filter Co., Style B.
(j) Bowden Single Valve Filter.
(k) International Filter Co., Style C.
(l) Crystal Fountain Filter Co., Dayton, O.

DISCUSSION

MR. J. M. DIVEN: This paper calls to mind a story: The lady of the house was getting her morning glass of water and asked the maid what was the trouble with the water that gave it such a peculiar taste. The maid replied, "The water is all right, mom, there are none of those live bugs or bacteria in it, I killed them." The mistress asked, "What did you put in to kill them?" "I put nothing in it?" "What did you do?" "Sure, I ran the water through the meat chopper twice before I put it in the cooler."

MR. F. L. RECTOR: The speaker has recently tested several types of household filters, five in all. In no case did they deliver a uniform effluent, and the average results of a test continuing for several weeks showed the filtered water to be higher in bacteria than the raw water. Counts as high as 20,000 per cubic centimeter were found in filtered water while raw water on a corresponding date showed only 14 per cubic centimeter.

These filters represented both the so-called "self-cleaning" type, and those using unglazed porcelain in some form.

The speaker does not consider any type of household filter effective, as the best they can do is to remove suspended matter from the raw water. Odors, tastes and bacteria will penetrate any of them. They give a false sense of security to the user by improving the appearance of the water, while actually adding to, rather than taking away the bacteria which may be present.

MR. J. M. DIVEN: If the city is not going to filter its entire water supply, the speaker believes that it is its duty to furnish pure water. If they are going to rely on household filters to furnish this pure water, it is up to the city to take care of the filters and see that they are properly sterilized and kept in condition. We do all that at our filter plant; we see that the filters are clean, that the clear water reservoirs are clean. Not one in ten thousand domestic consumers will see that their filters are in a sterilized condition. They are satisfied if the water comes through clear. If the turbidity is removed and the small fish taken out, and the water is cool and palatable, the filter is forgotten. It would probably be vastly cheaper for the city to filter the entire supply than to attempt to send inspectors to take care of several thousand household filters.

MR. SHEPPARD T. POWELL: The speaker's experience with household filters, and he has tested many different types, is that nine times out of ten the water is worse after it leaves the filter than when it enters.

MR. WILSON F. MONFORT: After a sufficiently long period of time has elapsed without cleaning such filters, there is no doubt whatever that the organisms do go through as mentioned in the paper; but probably the idea is that the results are better if the filters are taken care of properly. The speaker's experience some years ago was that the household filter is often left unattended, and one can get a nice slimy growth in the outlet. It is necessary that it be sterilized at least once or better twice a week, which seems to obviate the difficulty. The speaker has tried that in his own case and finds that it works out very nicely.

MR. SHEPPARD T. POWELL: Taking the general run of household filters that are left to the servants, very little attention is given them and you will generally find the effluent bad. This is because of the lack of care given to the filter rather than to any defect in its mechanical construction.

THE USE OF THE NITRITE TEST IN DETERMINING THE SOURCE OF POLLUTION OF A WATER SUPPLY

By William Miller Booth

Serious objection has recently been raised to the reliability and usefulness of the standard sanitary chemical tests for water. The object of this communication is to show how the nitrite test was applied to good advantage, in tracing a source of pollution.

The reservoir shown in the cut (fig. 1) consists of two excavations, walled at the sides, and fed by springs in the bottom. The land about slopes toward the reservoirs from the south, west and north, the natural outlet for the basin being toward the north-east. A small stream (*T*) overflows from the lower reservoir and joins a creek which is usually dry by the middle of summer, shown at *M*.

The water is pumped to a standpipe on the hill, shown at the right. This elevation is of shale and separates the watershed in which the reservoirs are located from the city at the other side. A highway passes at the base of the hill. A natural depression follows from a small wood at the south, northward, to the left of the highway.

When the writer was first acquainted with the locality it was timbered between stream and highway to the upper or first reservoir. This section was often used as a picnic ground. His first sanitary analysis of the water led to the suggestion that the reservoirs be cleaned. As several years had elapsed since this had been done, men were at once employed to do this. Although not shown in the tables, the ammonias soon lowered to the limit of an excellent potable water.

The writer next suggested that the woods property be purchased. This was cut over and the land was bought by the water company—an area of perhaps 20 acres.

In April, 1903, the writer made a second analysis, shown in table under No. 2. This easily places the water in the first class from a sanitary and bacteriological standpoint.

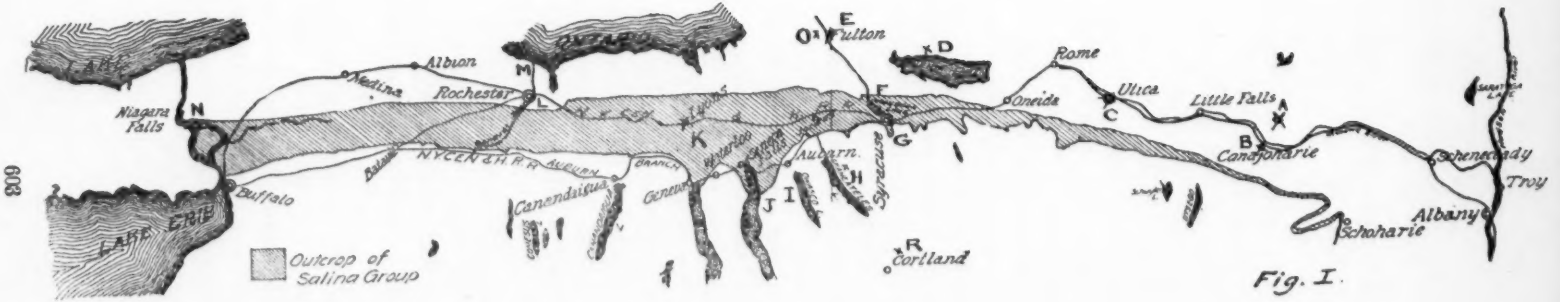

Albion
Medina
Rochester
Niagara Falls
Buffalo
LAKE ERIE
Canandaigua
Auburn.
Syracuse
Fulton
Rome
Oneida
Utica
Little Falls
Canajoharie
Schenectady
Troy
Albany
Schoharie
Cortland
Outcrop of Salina Group
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
R

Fig. I.

In May, 1906, a third analysis was called for to serve as a part of the record kept by the company. This showed the presence of nitrites and that the number of colonies on gelatine was unusually high for this water; the ammonias had also increased. The president of the company immediately called for a second analysis, which is shown in the table as No. 4. To the writer the conditions seemed alarming and he suggested immediate action in what seemed to be a case of serious pollution. The day but one following, a number of sample bottles and cases and the materials for the nitrite test as prescribed by Doctor Mason were taken into the field, freshly prepared solutions being used.

Two men were provided with a 10-foot length of inch iron pipe, with a perforated and pointed tip. This was driven at station I until about 8 feet had entered the ground. A pump was screwed in place and water elevated and allowed to waste for ten minutes. Sufficient was then bottled for further examination.

This operation was repeated at wells 2, 3, 4, 5, 6, 7 and 8. In the meantime the nitrite test was applied at A, 1, 2 and 3, with the results shown.

Crossing the stream the creek water from a pond through a meadow was tested. This developed a slight pink in five minutes. A small spring just across the stream at *X* showed a strong nitrite test at once. The writer looked just back of this and discovered two piles of swine in a partially decomposed state. There were eighty of these weighing perhaps 150 pounds each.

The problem of pollution was now pretty well solved but did not account for an abnormal nitrate test in the hollow between the road and the ridge south of the reservoir. Examination showed this to be the burial place for horses and cows that had died in the neighborhood. Further examination showed that the territory where the swine were found was the city garbage piggery and dog pound. Many of the latter had been chloroformed and buried in the vicinity.

To add to the unpleasant features of the situation, a partly decomposed Newfoundland dog was found near the reservoir from which sample No. 4 was taken. Please understand that the water from the reservoir supplied a town of 10,000 people.

The water company spared no expense to place the property in a sanitary condition. The analyses made from time to time

show how the water gradually righted itself and how serious results to the people were averted by a solid bank of sand between the piggery and the reservoirs.

In this and subsequent cases the writer has used the nitrite test to determine animal pollution with excellent results.

The owner of the pigsty was the chairman of the local board of health and himself a physician.

LOCATION	NO.	TOTAL SOLIDS	CHLORINE	FREE AMMONIA	ALB. AMMONIA	NITRATES IN NITROGEN	NITRITES IN NITROGEN	OXYGEN CONDENSED	CALORIES PER CC.	B. COLI	DATE	REMARKS
Syracuse	1	54	0.00	0.06	0.094	0.00	0.000	.....	.....	.....	Feb. 1910	Rain water
Syracuse	2	24	trace	0.02	0.025	0.005	0.006	.....	.....	.....	Nov. 1910	Snow water
Otselic	3	.....	8.8	0.002	0.002	0.00	0.0016	.....	.....	.....	Mar. 1903	Ice from pond
Cazenovia	4	.....	1.1	0.019	0.000	0.000	.....	.....	16	Absent	.....	Ice on lake
Syracuse	5	130	2.2	0.30	0.15	0.04	0.060	.....	.....	.....	June 1909	Cistern water
Syracuse	6	14	0.0	0.002	0.002	0.00	0.0005	.....	.....	.....	Aug. 1912	Distilled city water
Syracuse	7	120	1.0	0.005	0.045	0.40	0.000	.....	.....	.....	Aug. 1912	Raw water for No. 6
Syracuse	8	724	117.5	0.012	0.07	0.12	0.004	.....	.....	.....	Aug. 1910	Onondaga Creek
Syracuse	9	770	118	3.50	0.90	0.00	0.000	23.37	.....	.....	Aug. 1910	Onondaga Creek into lake
Syracuse	10	844	241	0.013	0.16	0.18	0.020	5.00	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	11	2674	1043	0.004	0.254	0.00	0.080	5.00	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	12	2744	1056	0.005	0.43	0.00	0.080	7.60	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	13	2584	1031	0.005	0.37	0.00	0.080	5.50	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	14	2600	1037	0.006	0.43	0.02	0.080	5.50	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	15	2454	1047	0.005	0.22	0.03	0.080	5.37	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	16	2848	1050	0.004	0.31	0.03	0.080	5.37	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	17	2720	1040	0.002	0.17	0.03	0.080	4.87	.....	.....	Aug. 1910	Onondaga Lake
Syracuse	18	2720	1072	0.002	0.23	0.03	0.080	4.75	.....	.....	Aug. 1910	.....
Syracuse	19	2606	1063	0.004	0.22	0.05	0.080	5.12	.....	.....	Aug. 1910	.....
Syracuse	20	1126	50	.....	2.84	.....	.....	.....	.....	.....	.....	Seneca River Junction
Syracuse	21	21456	9170	3.18	0.52	0.00	0.160	27.12	.....	.....	.....	Sewer outlet from city
Skaneateles	22	132	2.0	0.03	0.06	0.48	0.000	1.11	.....	.....	Oct. 1906	Lake supplying Syracuse (south end)
Skaneateles	23	122	2.0	0.015	0.055	0.45	0.000	1.01	.....	.....	Oct. 1906	40 ft. below surface; intake (north end)
Syracuse	24	127	1.94	0.000	0.062	0.36	0.000	0.87	28	Negative	.....	Intake; reservoir
Syracuse	25	124	1.94	0.000	0.075	0.35	0.000	1.12	.....	.....	.....	Outlet; reservoir
Syracuse	26	120	1.5	0.006	0.035	0.29	0.000	0.87	.....	.....	Nov. 22, 1905	Down town office
Skaneateles	27	260	5.0	0.070	0.165	0.52	0.012	2.12	.....	.....	Feb. 1909	Creek below lake outlet
Skaneateles	28	196	5.0	0.110	0.140	0.74	0.012	2.50	.....	.....	Feb. 1909	Creek below lake outlet
Skaneateles	29	310	8.0	0.050	0.270	0.80	0.012	6.00	.....	.....	Feb. 1909	Creek below lake outlet
Skaneateles	30	182	5.5	0.035	0.090	0.77	0.012	2.62	.....	.....	Feb. 1909	Creek below lake outlet
Fulton	31	136	14.0	0.102	0.52	0.02	0.000	8.17	.....	.....	June 1911	Lake outlet
Fulton	32	146	19.0	0.26	0.62	0.02	0.0005	10.9	.....	.....	.....	Polluted; above
Fulton	33	220	10.0	0.26	0.66	0.26	0.2000	11.0	.....	.....	.....	Polluted; above
Fulton	34	150	25.0	0.90	1.18	0.000	0.000	21.2	.....	.....	.....	Polluted; above

Fulton	35	520	57.5	10.80	2.06	0.000	0.000	20.42	.....	.....	.....	Polluted; above
Fulton	36	414	41.5	21.5	5.50	0.000	0.000	40.40	.....	.....	.....	Polluted; above
Fulton	37	1756	650	0.00	68.60	0.000	0.000	260.0	.....	.....	.....	Polluted; above
Charlotte	38	154	9.8	0.16	0.06	0.08	0.0003	0.40	30	Positive	Nov. 1912	Lake Ontario. Raw
Charlotte	39	152	11.6	0.10	0.04	0.10	0.000	0.42	22	Negative	Nov. 1912	Filtered
Fairport	40	154	9.8	0.08	0.07	0.08	0.000	0.55	130	Negative	Nov. 1912	Same at Fairport
Lockport	41	200	10.8	0.06	0.252	0.08	0.000	0.75	30	Positive	Nov. 1912	Niagara River water
Rochester	42	90	5.8	0.000	0.08	0.18	0.000	.....	20	Negative	Nov. 1912	Hemlock Lake supply
Seneca Falls	43	200	30.0	0.06	0.154	0.20	0.003	0.48	50	Negative	Nov. 1906	Intake—North end—Cayuga Lake (Booth)
Seneca Falls	44	170	31.0	0.03	0.08	0.40	0.005	1.50	.....	Negative	July 1907	Same Lederle Laboratories
Seneca Falls	45	180	30.0	0.00	0.09	0.23	0.002	0.48	40	Negative	Nov. 1906	House in city (Booth)
Seneca Falls	46	214	32.5	0.01	0.13	0.20	0.000	.....	.....	Negative	July 1907	Same Lederle Laboratories
Bridgeport	47	196	30.0	0.053	0.10	0.20	0.003	0.48	65	Negative	Nov. 1906	South of intake 12 ft. under
Lewis Pt	48	200	30.0	0.005	0.10	0.28	0.010	0.48	140	Positive	Nov. 1906	Further south 12 ft. under
Canoga Landing	49	180	30.0	0.000	0.092	0.25	0.002	0.36	34	Negative	Nov. 1906	Five miles south of intake
Cayuga Lake	50	268	51.0	0.000	0.08	0.20	0.000	1.30	20	Negative	Spring 1911	Two miles from intake, twelve feet under surface
Seneca Falls	51	270	51.0	0.07	0.18	0.22	0.0005	1.75	50	Negative	Spring 1911	House in city
Central New York	52	.....	8.0	0.013	0.110	.....	0.005	.....	.....	.....	Sept. 1902	Private water works (house faucet)
Central New York	53	116	4.0	0.000	0.040	1.00	0.000	.....	2	.....	Apr. 1903	Reservoir
Central New York	54	116	4.0	0.066	0.070	1.07	0.0065	.....	98	.....	May 17, 1906	Reservoir
Central New York	55	.....	4.0	0.047	0.041	0.75	0.0062	.....	1000	.....	May 28, 1906	Reservoir
Central New York	56	.....	4.0	0.015	0.071	0.66	0.0062	.....	.....	.....	May 30, 1906	Well No. 1
Central New York	57	.....	4.5	0.026	0.076	0.50	0.003	.....	.....	.....	May 30, 1906	Well No. 2
Central New York	58	.....	2.5	0.046	0.13	0.80	0.002	.....	.....	.....	May 30, 1906	Well No. 3
Central New York	59	.....	.....	.....	.....	.....	0.000	.....	.....	.....	May 30, 1906	Spring A
Central New York	60	.....	.....	.....	.....	2.00	.....	.....	.....	.....	May 30, 1906	Depression "C"
Central New York	61	.....	.....	0.000	0.105	0.84	0.046	.....	.....	.....	June 1, 1906	Well No. 4
Central New York	62	.....	.....	0.000	0.134	1.00	0.044	.....	.....	.....	June 1, 1906	Well No. 5
Central New York	63	.....	.....	0.002	0.135	0.74	0.044	.....	.....	.....	June 1, 1906	Well No. 6
Central New York	64	.....	.....	0.002	0.134	1.04	0.036	.....	.....	.....	June 1, 1906	Well No. 7
Central New York	65	.....	.....	0.002	0.090	1.04	0.036	.....	.....	.....	June 1, 1906	Well No. 8
Central New York	66	.....	.....	0.0015	0.003	1.08	0.006	.....	.....	.....	June 1, 1906	Reservoir
Central New York	67	.....	3.6	0.061	0.140	1.12	0.003	.....	.....	.....	June 5, 1906	Well at "C"
Central New York	68	.....	5.6	0.018	0.052	0.93	0.0065	.....	.....	.....	June 5, 1906	Reservoir
Central New York	69	.....	4.7	0.053	0.080	1.03	0.0065	.....	.....	.....	June 7, 1906	Reservoir

LOCATION	NO.	TOTAL SOLIDS	CHLORINE	FREE AMMONIA	ALB. AMMONIA	NITRATES IN NITROGEN	NITRITES IN NITROGEN	OXYGEN CONSUMED	CALORIES PER CC.	B. COLI	DATE	REMARKS
Central New York	70	.....	5.0	0.052	0.120	0.50	0.008	.....	.....	.....	June 9, 1906	Reservoir after storm
Central New York	71	.....	5.0	0.013	0.025	1.35	0.016	.....	.....	.....	June 13, 1906	Reservoir
Central New York	72	.....	5.0	0.005	0.020	1.19	0.005	.....	.....	.....	June 14, 1906	Reservoir
Central New York	73	.....	5.0	0.034	0.070	1.03	0.005	.....	.....	.....	Aug. 25, 1906	Reservoir
Central New York	74	.....	2.0	0.058	0.025	0.94	0.003	.....	.....	.....	Oct. 9, 1906	Reservoir
Central New York	75	160	4.5	0.000	0.015	0.88	0.003	.....	.....	.....	June 1907	Reservoir
Reservoir	76	139	1.6	0.006	0.018	0.85	0.002	.....	192	Negative	Dec. 1907	(Hazen & Whipple)
Faucet	77	145	1.62	0.008	0.020	0.50	trace	.....	4	Negative	Feb. 1908	State Board of Health Report
Faucet	78	147	1.75	0.020	0.012	0.80	trace	.....	60	Negative	Sept. 1908	State Board of Health Report
Filtered	79	494	46	0.026	0.005	0.10	0.000	0.92	475	.....	Nov. 1908	Mohawk River west of Fonda
Fulton	80	130	6.2	0.000	0.000	1.04	0.000	0.25	.....	.....	May 1910	City supply upper spring
Fulton	81	172	9.8	0.000	0.002	1.00	0.000	.....	.....	.....	May 1910	Second spring
Fulton	82	1108	441	0.006	0.044	0.16	0.000	1.12	.....	.....	May 1910	Great Bear spring
Fulton	83	442	144	0.020	0.016	0.40	0.000	.....	.....	.....	May 1910	Pump House
Paris, N. Y.	84	230	0.00	0.005	0.050	0.72	0.000	0.50	.....	.....	July 1907	County Springs (Booth)
Paris, N. Y.	85	229	2.28	0.018	0.052	0.40	0.000	1.12	.....	Present	Nov. 1910	Lederle Laboratories
Oneida County	86	264	.....	0.66	0.030	1.40	0.0009	0.75	.....	.....	.....	Supply for canning factory workmen
Onondaga County	87	112	2.1	0.010	0.040	0.50	0.000	0.45	.....	.....	Sept. 1908	Far from buildings
Northern New York	88	80	5.7	0.072	0.025	1.56	0.002	0.83	1020	Absent	July 1907	County spring
Tompkins Co.	89	333	11	0.00	0.05	0.00	0.000	.....	.....	.....	Nov. 1903	County spring used for bottled water
Intake	90	140	0.00	0.000	0.020	0.20	0.000	0.90	900	Present	Nov. 1912	New town supply Mohawk Valley
Town	91	140	0.00	0.012	0.016	0.20	0.000	0.92	450	Present	Nov. 1912	New town supply Mohawk Valley
Lyons	92	2170	45	2.20	0.27	0.00	0.001	.....	2000	Absent	.....	New wells about 60 ft deep
Lyons	93	4880	700	0.38	0.05	0.00	0.000	.....	400	Absent	.....	All abandoned
Lyons	94	3006	45	5.64	0.05	0.00	0.000	.....	500	Absent	.....	
Lyons	95	3780	260	2.14	0.10	0.10	0.000	.....	.....	.....	.....	
Adirondacks	96	20	40	0.02	0.24	0.40	0.000	1.61	10000	Absent	July 1908	Several deaths from typhoid at a private club
Adirondacks	97	60	40	0.04	0.17	4.00	0.003	0.73	210	Absent	July 1908	
Adirondacks	98	.....	0.00	0.025	0.175	1.60	0.000	2.00	26250	.....	July 1908	
Adirondacks	99	.....	0.00	0.056	0.40	0.23	0.000	.....	.....	.....	Nov. 1908	New wells on high ground. No further trouble
Adirondacks	100	84	1.0	0.05	0.15	2.6	0.003	2.15	14	Absent	.....	
Private	101	397	12	0.60	0.10	18.0	0.001	.....	9300	Present	Nov. 1909	Well 18 ft. from stable 20 ft. deep
Private	102	.....	.....	.....	.....	.....	.....	.....	430	Absent	Nov. 1912	Barn made garage. 1910 new
Manufacturing	103	724	100	0.20	0.05	1.45	0.030	5.70	315	Present	Sept. 1908	530 ft. well through rock

Plant	104	564	89	0.37	0.02	0.20	0.800	1.12			Nov. 1908	Contains hydrogen
Plant	105	504	76	0.16	0.02	0.40	0.050	0.90	8	Absent	Dec. 1908	Sulphide and is not used 60 ft. deep
Private	106	2480	40.5	0.14	0.026	1.22	2.72	1.62			Oct. 1906	Condemned
Private	107	1332	14.0	0.08	0.025	10.00	0.005				May 1906	Condemned
Utica	108	4520	307	0.82	0.02	0.00	0.000					1200 ft. deep, discarded
Texas	109	3794	1770	0.000	0.050	0.00	0.020	2.3				Well in Texas desert
Oswego, N. Y.	110			0.66	0.24	0.00	0.000					Used as a mineral water
Albany, N. Y.	111	700	26	0.00	0.00	0.000	0.000					An unusual water
Syracuse	112	1680	27	0.10	0.02	9.62	0.28	1.95				Well 60 ft. deep abandoned
Private	113	166	2.3	0.001	0.009		0.000	Before pollution			July 1902	Wells polluted
Private	114		88.0	0.50	0.05			After pollution			Oct. 1902	by cheese factory
Private	115		88.0	0.50	0.06			After pollution				Waste
"Utica"	116	6000	3270	(0.31)		0.00	0.000	55.0				New "mineral water" well
Syracuse	117	3388	11	0.010	0.010	0.00	0.010	1.12			July 1909	Two 200 ft. wells discarded
Manlius	118	11580	4570									220 ft. well discarded
McGraw	119	110	2.0	0.006	0.32	1.24	0.000				Aug. 1908	120 ft. well, new
McGraw	120	100	.10	0.02	0.025	1.00	0.000				June 1909	120 ft. well, second analysis
Oneida Lake	121	144	0.00	0.02	0.06	0.00	0.00					Taken in Feb. 1904 through ice
Otisco Lake	122	109	3.0	0.04	0.03	0.07	0.002				Feb. 1910	
Contrexville (mineral water)	123	2670	10	0.02	0.025	0.025	0.025				Oct. 1908	Bottled in France
New Syracuse	124	268	1.5	0.005	0.020	1.60	0.0005				Nov. 1912	
New Syracuse	125	229	2.6	0.020	0.040	0.20	0.0005				Nov. 1912	Country springs south of Syracuse
New Syracuse	126	142	1.6	0.000	0.020	1.06	trace	0.22	Pumping 10 min. (5)		Nov. 1912	
10 ft	127		10.8	0.00	0.02	1.20	0.000	0.22	Pumping 12 min. (5)	Absent	Oct. 1907	Well driven in shale
20 ft	128		10.2	0.01	0.005	1.28	0.000	0.22	15 min. pumping (1)	Absent	Oct. 1907	Well driven in shale
40 ft	129		9.0	0.00	0.005	1.12	0.000	0.10	20 min. pumping (4)	Absent	Oct. 1907	Well driven in shale
	130											
	131											
	132											
	133											
	134											
	135											
	136											

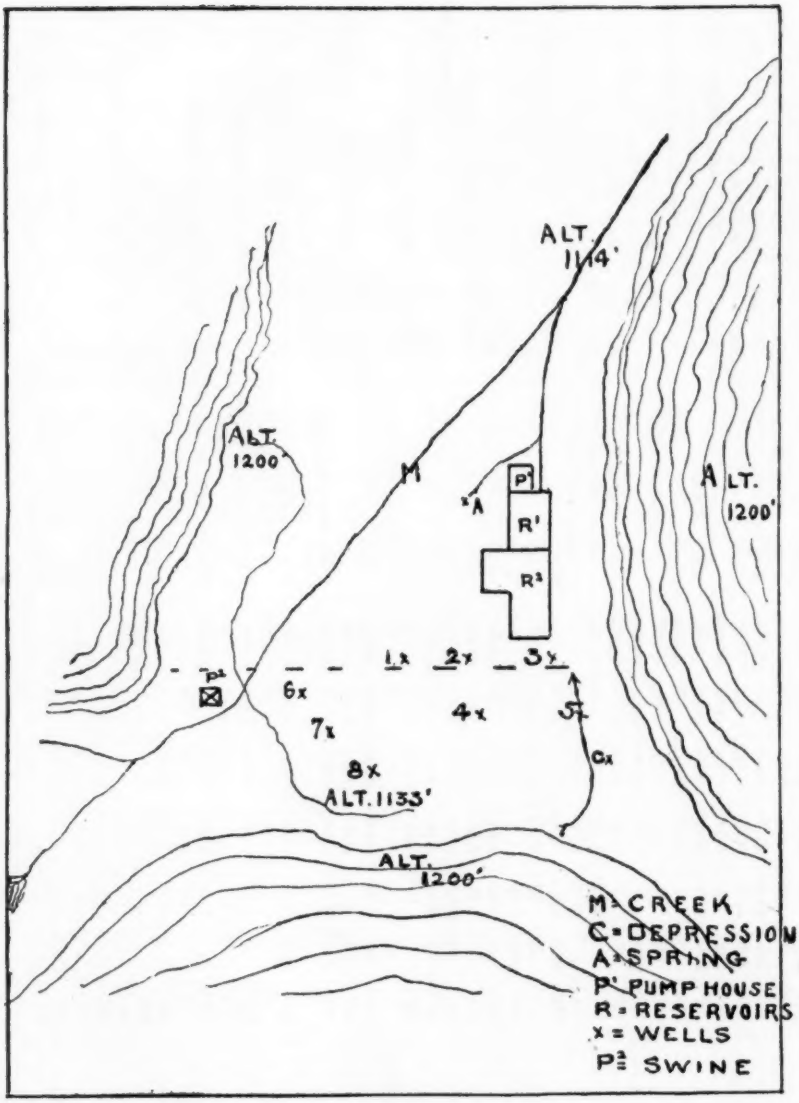

ALT. 1114'
ALT. 1200'
M
P¹
A
R'
R²
ALT. 1200'
P²
1x
2x
3x
6x
4x
5x
7x
8x
Cx
ALT. 1133'
ALT. 1200'
M = CREEK
C = DEPRESSION
A = SPRING
P' PUMP HOUSE
R = RESERVOIRS
x = WELLS
P² SWINE

FIG. 2

DISCUSSION

PROF. J. M. CAIRD: With reference to getting distilled water free from nitrite, is it possible that in a laboratory where a large amount of gas is used this will sometimes prevent getting water free from nitrites?

MR. SHEPPARD T. POWELL: The speaker has found that in the laboratory where we were using gas we got nitrites right along, but after changing over to the use of electric heat, we did not get any nitrites in the distilled water. When you were collecting your distillate, did you seal the tubes with absorbent cotton?

MR. WILLIAM MILLER BOOTH: That was tried, but it did not seem to make any difference in the result so far as nitrites were concerned.

DIAGRAMMATIC METHOD OF DETERMINING THE COST PER FOOT OF CAST IRON PIPE

By W. E. Miller

Since the costs and values of cast iron pipe are usually wanted in terms of dollars and cents per lineal foot, and the purchase is usually made on a tonnage basis, it has heretofore been necessary to make calculations of the costs per foot every time such a figure is wanted.

A straight edge and the accompanying diagram, if kept handy, will be a very convenient and satisfactory means of quickly obtaining the cost per foot of any common size of cast iron pipe in the American Water Works Association classes A, B, C and D, from any price per ton.

The diagram is mathematically constructed on logarithmic scales. The results sought may be read direct on the central scale by the straight edge laid across the price per ton on the left hand scale, and the size and class on the right hand scale.

In using the right hand scale care should be taken to use the points on the vertical line, not the numerals to the left and right of it. It will be noted in this connection that the size numerals each occur four times and are arranged in four columns under the class letters, and are opposite the proper points on the vertical scale.

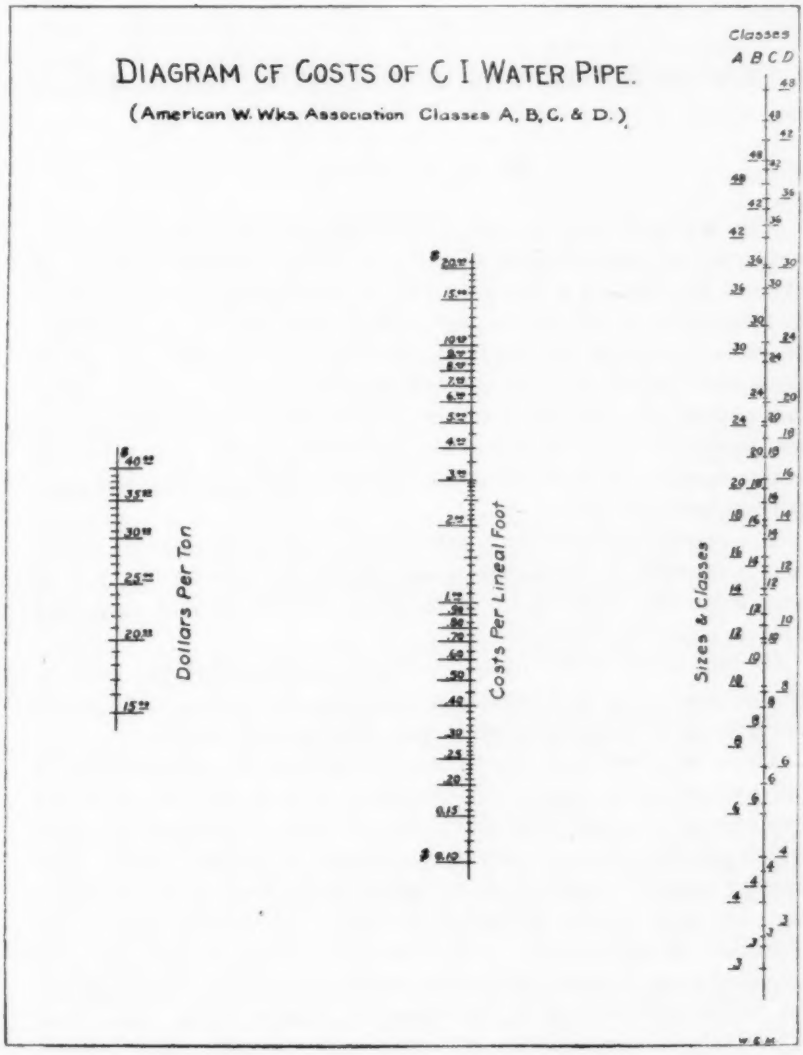


DIAGRAM OF COSTS OF C I WATER PIPE.
(American W. Wks. Association Classes A, B, C, & D.)
Dollars Per Ton
Costs Per Lineal Foot
Sizes & Classes
Classes
A B C D

THE INDIVIDUALITY OF PUBLIC UTILITIES, NOTABLY WATER WORKS

By W. E. Miller

The fact that there has been a popular tendency in the past to measure the reasonableness of rates of one public utility plant, or even to fix rates for a new plant, by a comparison of those in force in other cities seems to warrant a little consideration of the differences between various plants of like kind and between the conditions under which they are constructed and operated. These differences seem generally far from being fully appreciated except by the comparatively few who have had something to do with a considerable number of such properties and had occasion to make comparison between them.

The popular comparison of rates of different water or other utility plants appears to be merely a superficial one, due to the lack of knowledge and appreciation of the great differences that may exist even in cities of similar size.

Certain water works franchises have specified that the rates to be charged by the grantees under those franchises should not exceed the average of those in certain other cities named therein.

Those who have had experience in construction and valuation of railroad property, and doubtless others as well, are aware of the existence of a wide range of values per mile of roadbed or track, which are the common bases of comparison of different roads. The heavier types of construction on heavy traffic roads is by no means the only cause of the differences in costs or values per mile. Construction difficulties may be relatively so serious in the case of a so-called small road, or light traffic road, as to offset the extra expenses for stiffer construction in the cases of certain higher class lines. These relative construction difficulties may, in other cases, operate to augment, instead of to offset, the differences in cost that are due merely to construction standards. Topography and geology of the country traversed are important factors in the results.

In the field of waterworks construction there are many different factors and combinations of them which enter into the costs of plants. The mere costs of prospecting for and developing water supplies for relatively small communities have often been relatively, if not actually greater than in the cases of much larger cities, particularly so when the losses involved in necessary changes from one source to another, if not to a third and even a fourth source, are considered.

Topography and geology are factors as influential in the costs of water plants as they are in railroads. Even climate is an important consideration since it affects the depths at which mains and services are to be laid and the character of other features. One does not have to travel very far in certain sections to find standard trench depths differing quite remarkably. For example, at Chippewa Falls, in the west central part of Wisconsin, the franchise granted to the water company required a depth of 9 feet of cover, which involved cutting into a considerable amount of solid rock. At Hurley, on the north line of Wisconsin, and Ironwood, in upper Michigan, the water mains are laid in a trench only 5 feet deep and it is understood that very little, if any trouble through freezing of mains has occurred. Heavy snow covering throughout the winter is given as the reason for the comparatively shallow penetration of frost in those places.

Milwaukee's specifications for pipe laying call for a depth of $6\frac{1}{2}$ feet to the center of pipe.

Within the state of Wisconsin alone the standard depths of cover on water mains in different cities have been found to range from $4\frac{1}{2}$ feet to 9 feet.

It seems needless to say that the character of material to be excavated and the cost of excavating it have also varied between wide limits, covering everything from a merely damp loamy sand, requiring no use of picks, sheet piling or pumps, to solid rock, involving drilling and blasting, or to wet sand and gravel requiring tight sheathing and much pumping.

Conditions very favorable to low cost of pipe laying predominate in some cities while in others the work is very difficult almost throughout. One small city in Wisconsin within the writer's knowledge has found it impracticable to finance the construction of a water works solely because of the fact that the pipe laying would involve the expense of almost continuous excavation of solid rock.

In discussing the distribution system, which forms so large a part of the cost of every water works plant, it is also of interest to note how various plants differ as to average size of pipe in mains. This, as well as the cost of laying, materially affects the total investment. Some water pipe systems contain a considerable proportion of small wrought iron and steel pipe, ranging from $\frac{3}{4}$ inch to 3 inch running longitudinally with the streets and classed as mains, although serving only private consumers, while other cities have nothing smaller than 4 inch or even 6 inch pipe.

Below is a tabulation for a number of Wisconsin water plants, showing for each case the population by 1910 census, the total mileage of mains and the average pipe diameter. The average size was determined by multiplying each diameter by the length of that size and dividing the sum of those products by the total length of all sizes.

TABLE I

Class A Plants

PLACE	POPULATION	MILES OF MAINS	AVERAGE DIAMETER INCHES
Private Ownership			
Ashland	11,594	30.70	6.87
Beloit	15,125	27.55	6.38
Chippewa Falls	8,893		
Green Bay	25,236	96.74	4.13 (Lowest)
Janesville	13,894	32.55	5.60
Marinette	14,610	33.66	5.22
Merrill	8,689	19.92	5.49
Oshkosh	33,062	60.34	6.23
Racine	38,002	76.43	7.06
Superior	40,384	61.82	7.95 (Highest)
Municipal			
Appleton	16,773		
	All sizes	29.72	
	C. I. only	22.62	5.57
Eau Claire	Pipe data not	available	6.79
Fond du Lac	18,797	33.62	5.81
Kenosha	21,371	41.93	6.12
La Crosse	30,417	63.97	8.22
Madison	25,531	51.13	5.18 (Lowest)
Manitowoc	13,027	24.63	6.94
Milwaukee	373,857	499.00	8.61 (Highest)
Sheboygan	26,398	68.50	5.69
Watertown	8,829	20.59	6.46
Waukesha	8,740	25.86	6.70
Wausau	16,560	31.92	5.33

Class B Plants

Private			
Antigo	7,196	13.97	5.46
Beaver Dam	6,758	16.67	6.17
Mellen	1,833	3.68	6.30
Menomonie	5,036	10.91	5.65
Oconto	5,629	14.48	5.28 (Lowest)
Ripon	3,739	11.63	5.92
Stevens Point	8,692	16.04	6.09
Washburn	3,830		
	All sizes	8.43	5.50
	4" and larger	6.67	5.55

TABLE I—Continued

Class B Plants—Continued

PLACE	POPULATION	MILES OF MAINS	AVERAGE DIAMETER INCHES
Private			
Whitewater	3,224	8.76	6.83 (Highest)
Municipal			
Baraboo	6,324	14.36	6.20
Berlin	4,636	9.58	6.57
Columbus	2,523	6.86	5.51
Edgerton	2,513	6.52	5.69
Fort Atkinson	3,877		
	4″ and larger	8.78	5.20
	All sizes	10.38	4.90
Grand Rapids	6,521	16.65	5.26
Hudson	2,810	8.78	4.69
Kaukauna	4,717	10.46	6.88
Lake Geneva	3,079	7.72	5.89
Lancaster	2,329	8.59	4.44
Marshfield	5,783	8.99	7.72
Menasha	6,081	13.29	7.87
Monroe	4,410	8.98	5.39
Neenah	5,734	13.75	6.53
New Richmond	1,988	3.22	5.63
New London	3,383	5.87	5.70
Platteville	4,452	14.65	4.75
Portage	5,440	18.37	4.24 (Lowest)
Port Washington	3,792	7.17	6.40
Rhinelander	5,637	15.28	5.92
Rice Lake	3,968	9.76	4.73
Richland Center	2,652	7.68	5.05
River Falls	1,991	5.16	5.65
Shawano	2,923	5.94	5.36
South Milwaukee	6,092	7.72	6.17
Sparta	3,973	12.95	4.93
Stoughton	4,761	13.37	4.43
Sturgeon Bay	4,262	1.84	9.43 (Highest)
Tomah	3,419	7.63	4.74
Tomahawk	2,907	5.31	5.49
Two Rivers	4,850	10.05	4.61
Waupaca	2,789	9.71	5.27
West Allis	6,645	27.90	6.55
Oconomowoc	3,054	8.74	6.88
Plymouth	3,094	9.83	4.89

In addition to the foregoing, the following similar statistics for certain water plants outside of Wisconsin are available:

PLACE	POPULATION	MILES OF PIPE	AVERAGE DIAMETER INCHES
Chicago, Ill.....	2,185,283 (1910)	2,362.00 (1911)	8.62
Indianapolis, Ind.	233,650 (1910)	364.10 (1914)	8.28
Charleston, W.Va.	32,000 (Est. 1914)	52.37 (Jan. 1, 1914)	4.46
Pennsylvania Water Co., Wilkinsburg, Pa...		146.90 (1910)	8.78

The foregoing figures were, in most cases, compiled from statistics furnished by the plants for the year ending June 30, 1913. In a few instances statistics on pipe mileage for that year were not available and those of somewhat earlier dates were used, being taken from inventories and valuations.

In those cases where much pipe smaller than 4 inch is used it is evident that the fire service is either not coëxtensive with the pipe system or it is of a lower order of excellence than in those cases where no such small pipe is found.

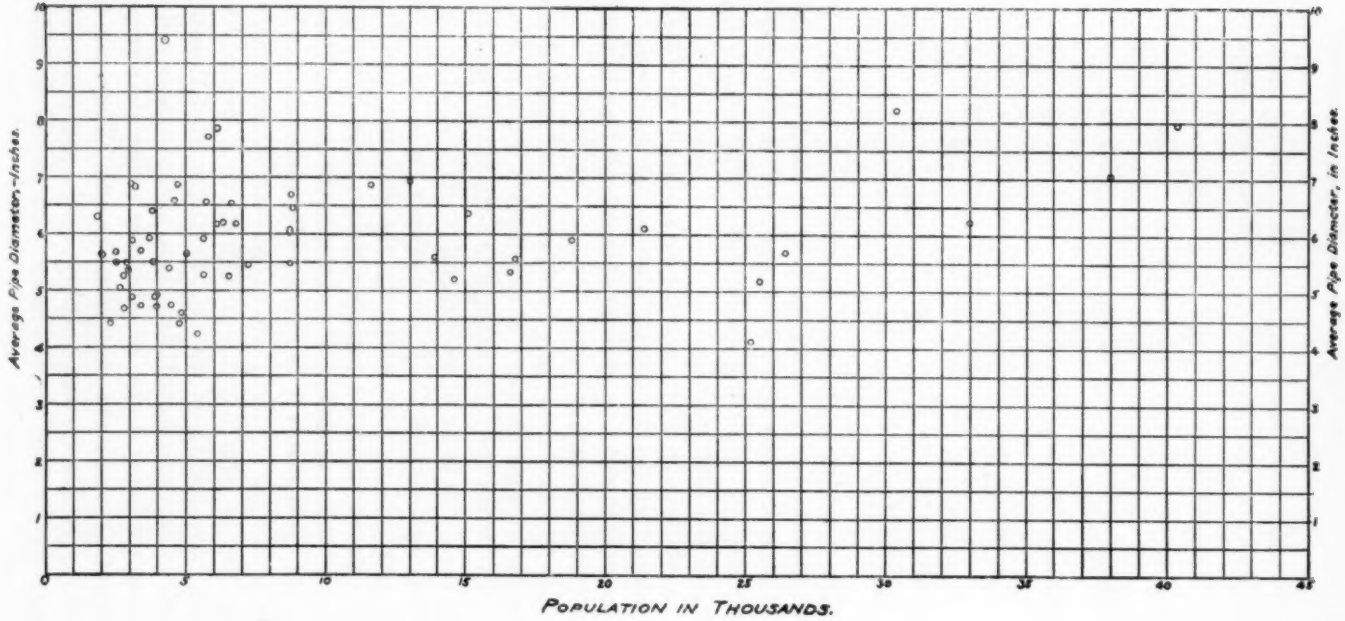
The question sometimes arises as to how marked is the tendency for the average diameter of distribution mains of a water plant to increase with the total mileage or with the population of the cities supplies. In order to most clearly show that tendency so far as the foregoing figures indicate its existence those values have been put in graphical form as shown by the diagrams (fig. 1) and (fig. 2). The former shows the various cities arranged in the order of magnitude of their population, the second in the order of total pipe mileage.

The great diversity of average pipe diameters can hardly be fully accounted for by differences in local conditions alone but are doubtless due in large measure to differences in personal ideas of those who have had to do with the development of these systems. It is also to be remembered that these several plants will certainly not show the same degree of adequacy under their respective sets of operating conditions and requirements. They are all, doubtless, fully adequate for the ordinary daily commercial service, but the capacity for good direct pressure fire service in addition is low in

FIG. 1

SHOWING VARIATION IN AVERAGE DIAMETERS OF WATER MAINS IN 64 WISCONSIN CITIES

Cities arranged in order of population



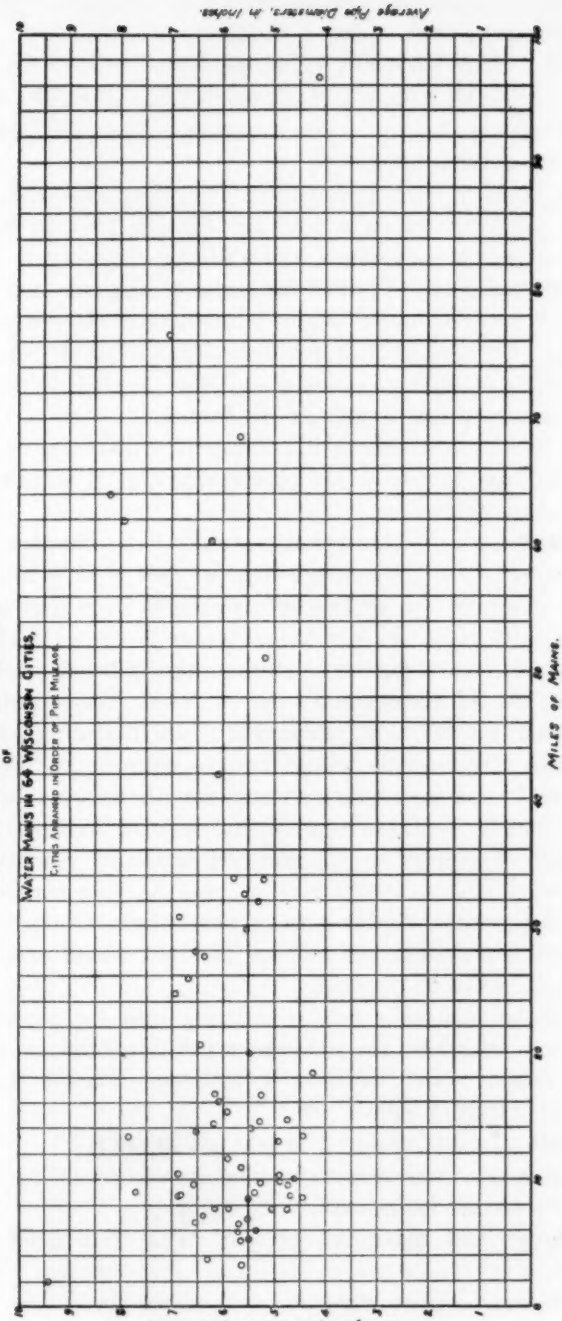


FIG. 2

SHOWING VARIATION IN AVERAGE DIAMETERS OF WATER MAINS IN 64 WISCONSIN CITIES.

Cities Arranged in Order of Pipe Mileage.

those cities where average pipe diameters are small. In two cities of similar size and having very similar pipe systems the fire service will be poorer in that one using the greater amount of water in the general commercial service.

It can scarcely be contended that the diagrams (figs. 1 and 2) establish the existence of a tendency for the average diameter of mains in a system to increase as the mileage increases or as the city grows in population. The developments of single or individual systems would be much more reliable indications of the natural changes in average pipe sizes, as the great diversity of ideas of those in charge of extensions of various systems and the great diversity of other local conditions would largely be eliminated.

Figure 3 shows the change in average pipe diameter with increase in total mileage in two water pipe systems in Wisconsin, those of Madison and Milwaukee.

In order to indicate the approximate effect of difference in average pipe diameter upon the average cost per foot of all mains in a system, the diagram (fig. 4) has been prepared from unit prices used in 1911 valuation of the Milwaukee Water Works. That valuation was made by the engineering staff of the railroad commission of Wisconsin for the commission's use in determining equitable rates. The diagram shows values per foot of mains including material and labor costs. These unit values are, of course, not applicable in valuation of other pipe systems where conditions are different. The diagram merely indicates approximate relative unit values on different sizes, or average sizes, under certain specific conditions.

Were all conditions except average pipe diameter similar in Madison and Milwaukee, figures 3 and 4 would indicate that the cost of the Milwaukee system per mile or per foot would exceed that of Madison by about 60 per cent.

Among the numerous factors entering into the problem of the pipe system and into the differences existing between the several systems named above, both as to average diameter and cost per foot or other unit of length, are:

1. Depth of cover required to prevent freezing.
2. Character of soil as regards difficulty of excavating it.
3. Rates of cost for materials and labor.
4. Average and maximum present rates of demand of private service.

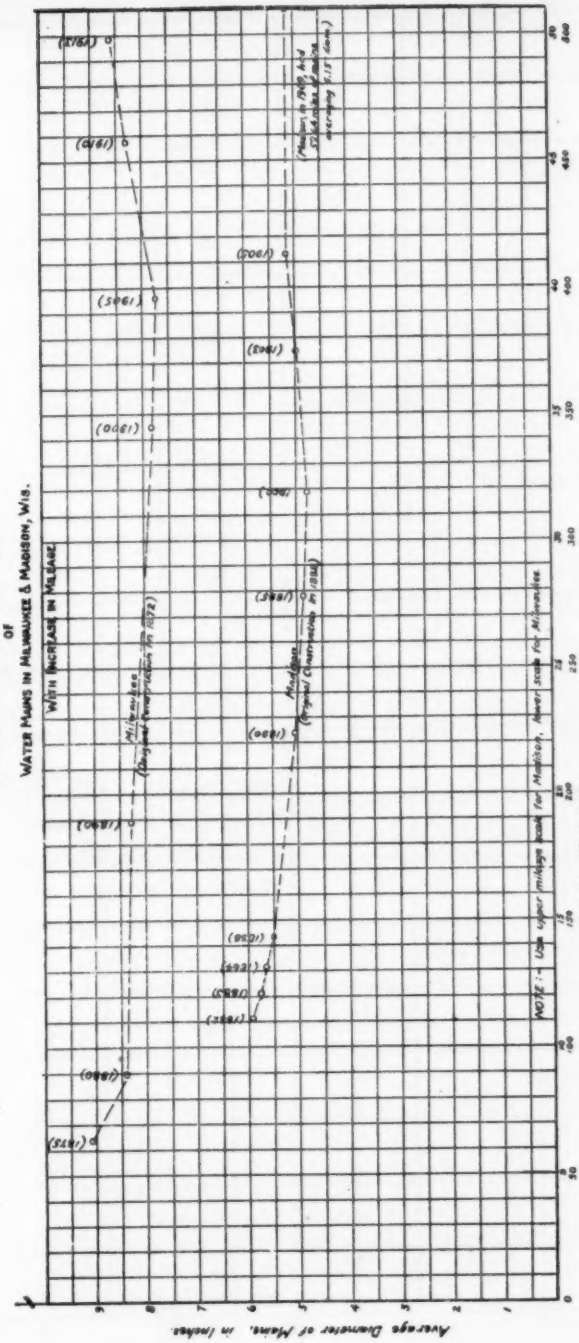


FIG. 3.

SHOWING CHANGES IN AVERAGE DIAMETERS OF WATER MAINS IN MILWAUKEE & MADISON, WIS. WITH INCREASE IN MILEAGE.

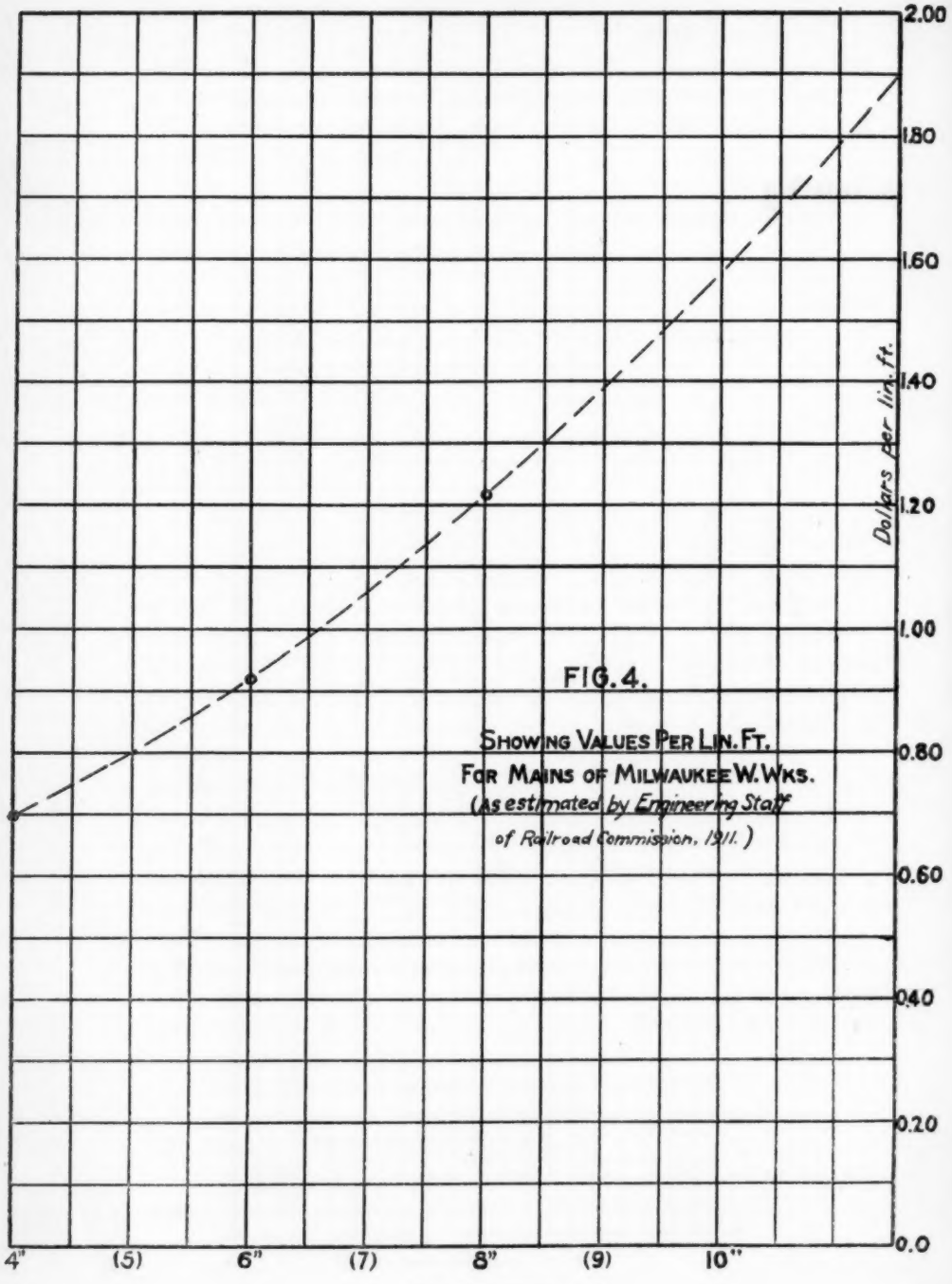


FIG. 4.

SHOWING VALUES PER LIN. FT.
FOR MAINS OF MILWAUKEE W. WKS.
(As estimated by Engineering Staff
of Railroad Commission, 1911.)

5. Provision or lack of provision of a temporary surplus of capacity to take care of future extensions into new territory.

6. Provision for increased demand in existing territory.

7. Provision for reduced carrying capacity by incrustation or tuberculation.

8. Character of fire service to be provided.

9. Location of pumping plant with respect to center of distribution.

10. Permissible total loss of head by friction (affected by topography of territory) etc.

A little reflection on the number of factors that affect the design, development and cost of a water pipe system, and on the range of values any one factor may have in different cases shows that it is but natural for such systems to possess decided individuality.

The entire distribution system of a public water works property often represents two-thirds or even a greater proportion of the total plant value, yet in a number of cases it falls to materially less than one-half the total. Such differences are, in part, due to lack of uniformity in the matter of ownership of service pipes and meters, these being generally counted as parts of the distribution system in cases where they are installed by and at the expense of the water works, instead of by property owners or tenants, as is the custom in some cities.

While the foregoing and other facts show that very little is to be gained by merely comparing total water plant investments or valuations in different cases on any basis, it is considered of some interest to note how such total values do vary.

Thirty-three of the Wisconsin water works plants of which physical valuations have been made by the engineering staff of the railroad commission of Wisconsin for the commission's use and consideration in rate or purchase cases compare as follows on the "per capita" basis:

2	Plants showed values between	$14.70 and	$15.00
14	Plants showed values between	15.00 and	20.00
10	Plants showed values between	20.00 and	25.00
4	Plants showed values between	25.00 and	30.00
2	Plants showed values between	30.00 and	35.00
0	Plants showed values between	35.00 and	40.00
1	Plant showed a maximum of	40.96	
33	Plants showed an average of	$21.34	

The same plants compared on the basis of total physical valuation per service connection show the following relative amounts:

2	Plants had values between	$75.00 and	$100.00
12	Plants had values between	100.00 and	150.00
10	Plants had values between	150.00 and	200.00
5	Plants had values between	200.00 and	250.00
4	Plants had values between	250.00 and	300.00
33	Plants averaged		$171.91
22	Plants in the largest groups averaged		$146.95

When compared on the investment per million gallons pumped during a year these plants appeared as follows:

5	Plants furnished no pumping statistics		
3	Plants had values between	$380 and	$400
4	Plants had values between	400 and	500
9	Plants had values between	600 and	703
5	Plants had values between	800 and	1000
6	Plants had values between	1000 and	1300
1	Plant had maximum value of $6028		

On this basis of comparison it is seen that the capital charges for each million gallons of water pumped, if computed at the same rate for all, were almost sixteen times as much in the highest case as in the lowest.

The valuations to which reference has been made herein were not the final and official valuations fixed by the commission on the utilities as going concerns but included merely the physical property. The fact that the difference between the two is often quite considerable appears to be far from being generally realized.

Not only do public utilities vary widely as to comparative costs or values but they serve communities having decided peculiarities and individualities of their own. Great differences are found in the average wealth of the inhabitants of various cities, in the extent and character of the industries located therein, in the topography and geology of the land on which they are built and in other aspects. All these decisively affect the demands on the utilities and therefore their operating expenses, and necessary rates.

A comparison of the pumping expenses alone of 17 of the larger Wisconsin water plants, excluding Milwaukee, showed a range of from $10.38 to $32.32 per million gallons during the year ending June 30, 1913. The head pumped against, not including suction

lift, varied from 100 feet to about 230 feet. There was apparently but little relation between the pumping pressure and the cost per million gallons pumped. Some of the plants in Wisconsin pump against a domestic pressure of as low as 70 foot head while just across the state line is one (in Duluth) which raises water (in three lifts) from Lake Superior to an elevation of about 900 feet.

The extra expenses of pumping the same water twice, once from deep wells to a low reservoir or from a lake or stream to a purification plant, then to the city mains and the expenses of purification are material elements in the total cost of service of some plants and are not present in that of others.

Some plants are found to be furnishing service to substantially all, and others to less than half of the inhabitants of their respective communities. Even if all cities were built equally compact, this variation in proportions of population served would materially affect the number of consumers per mile of mains, or in other words, the number of feet of mains for each consumer in the cases of different utilities.

Most cities show some growth. In certain cases this has been positive, permanent and rapid, in others it has been very slow, even to a negative growth or reduction. Rapidity of community growth affects the depreciation accruing to the utility through obsolescence and inadequacy, causing replacements and enlargements before existing facilities have become worn out.

One of the very important differences between the rates of various water utilities is in the manner in which the total expense has been divided between the public and the private service. By the public service is meant that included in the hydrant rentals. By private service is meant all the remainder, which is sometimes designated as the general service and subdivided into classes termed domestic, commercial and industrial service.

Until a very few years ago the determination of hydrant rentals seems to have rarely, if ever, been put upon a scientific and equitable basis. Such charges were generally, if not always, fixed by a process of bargaining between municipal authorities and the owners or managers of the utilities. The latter naturally got what they could of their total revenues in the form of hydrant rentals and endeavored to spread the balance of the total expense of operation and fixed charges over the general service.

There is probably no need of reproducing here any of the abundant

published data showing how greatly the hydrant rentals have varied in different cities. That such great differences exist seems to be quite widely known. Obviously, if a water works is to have a fair and proper gross income, it must make up from the private consumers, or water takers, whatever amount of fair revenue it fails to get in return for its municipal hydrant service. Rates for the former are clearly dependent in part upon whether or not the latter service yields its just proportion of the total expense.

These and numerous other considerations which might be mentioned, all demonstrate quite clearly that every water plant at least, if not every public utility, has its own peculiarities and individuality. The best interests of both the utility and the public it serves, demand that it be considered separately and independently of all others, except perhaps when all the differences in local conditions are fully understood and due allowances are made therefor. The law of averages has its uses but it certainly is not applicable in determining reasonable rates for one plant by those of others.

In making comparisons between various water plants, for example, it is to be remembered that the statistics of each plant are continually changing and in some cases much more rapidly than others. At any given time the business of each plant in any list that may be taken is in a particular stage of its development and that of each plant is likely to be quite different from all the others. In the writer's judgment these considerations all demonstrate quite clearly that each plant is to be considered upon its own particular conditions and merits as a special case having decided individuality.

SOME OBSERVATIONS OF THE EFFECT OF OZONE ON ALGAE GROWTHS

By S. T. Powell

For the past five years the Baltimore County Water and Electric Company, under the supervision of Mr. A. E. Walden, has been using ozone as a sterilizing agent to purify their Herring Run water supply. The system as it was originally installed did not accomplish the results that were expected in many ways, so that it became necessary to entirely redesign the plant several times and this has necessitated much research, as little information could be obtained from any of the European plants in operation. It is not, however, the object of this paper to recite the details of the work that has been done, but merely to relate the effect of ozonization upon certain types of micro-organisms.

Herring Run is a small surface water stream that flows for the most of its course through a thickly populated territory and receives more or less surface drainage, so that there is always an appreciable amount of matter carried in suspension by the supply. Before reaching the ozone plant the water is stored for about twenty-one days in two earthen reservoirs from which a portion, but not all, of the top soil was removed before they were placed in use. Algae and other vegetable growths have always been more or less prolific in the supply and it has been necessary to treat the water many times each year with copper sulphate to keep down these objectionable growths. Up to the present time the water flowed to the ozone plant direct from the reservoirs without prefiltration and for this reason we have been afforded an opportunity to note the effect of ozone as an algaecide.

The method of mixing the ozone and water is by means of aspiration, the falling water sucking the ozone directly from the generators, and is carried through a mixing chamber and from there delivered to the suction well of the pump. This well is open to the atmosphere so that the ozone not used up during passage through the mixing chamber is allowed to escape at this point.

It was noticed that very soon after putting the plant in operation a foamy greenish scum collected on the surface of the water, which increased in thickness the longer the plant operated and had to be removed by overflowing the well. Microscopic examination showed that the accumulation was due to algae growths to which had adhered small bubbles of ozonized air and had carried the organisms to the surface of the water. It was evident also that the ozone had a disintegrating effect on many of the organisms, especially the chlorophyceae and cyanophyceae. The analyses of samples of water before and after ozonization showed that the treatment had materially reduced the total number of organisms, as well as the amorphous matter. The percentage removal varied from day to day but not uniformly with the changes in the ozone concentration. It was evident that although the reduction showed the extent to which the organisms were eliminated from the water, this was by no means due entirely to oxidation by the ozone, but partly on account of breaking up of the more delicate organisms by the violent agitation of the water in passing through the mixing chamber, and to the formation of scum on the surface of the water in the suction well.

For this reason laboratory tests were made to determine to what extent the algae were killed by direct contact with the gas, and the general effect on the water resulting from ozonization of samples impregnated with such vegetable growths, especially with reference to color and odor.

LABORATORY TESTS AND APPARATUS

For this work an air ozone generator was used, the top of which was removed and replaced with a tightly fitting hood from which the ozone could be drawn without dilution from the air of the room. The general arrangement of the apparatus used is shown in chart I. One-half a liter of water to be tested was placed in the absorption bottle *B* and the ozone generated in *A* was aspirated through the bottle by means of the nozzle *C*. Only low concentrations (0.20 to 0.30 gram per cubic centimeter) could be obtained from the generator used, but in our experiments we have noted that low concentration and long contact will usually ensure as thorough oxidation of organic matter as higher concentration and short periods of contact. The ozone was drawn through the water at the rate of one liter per minute so as to prevent violent agitation, which would break up the algae.

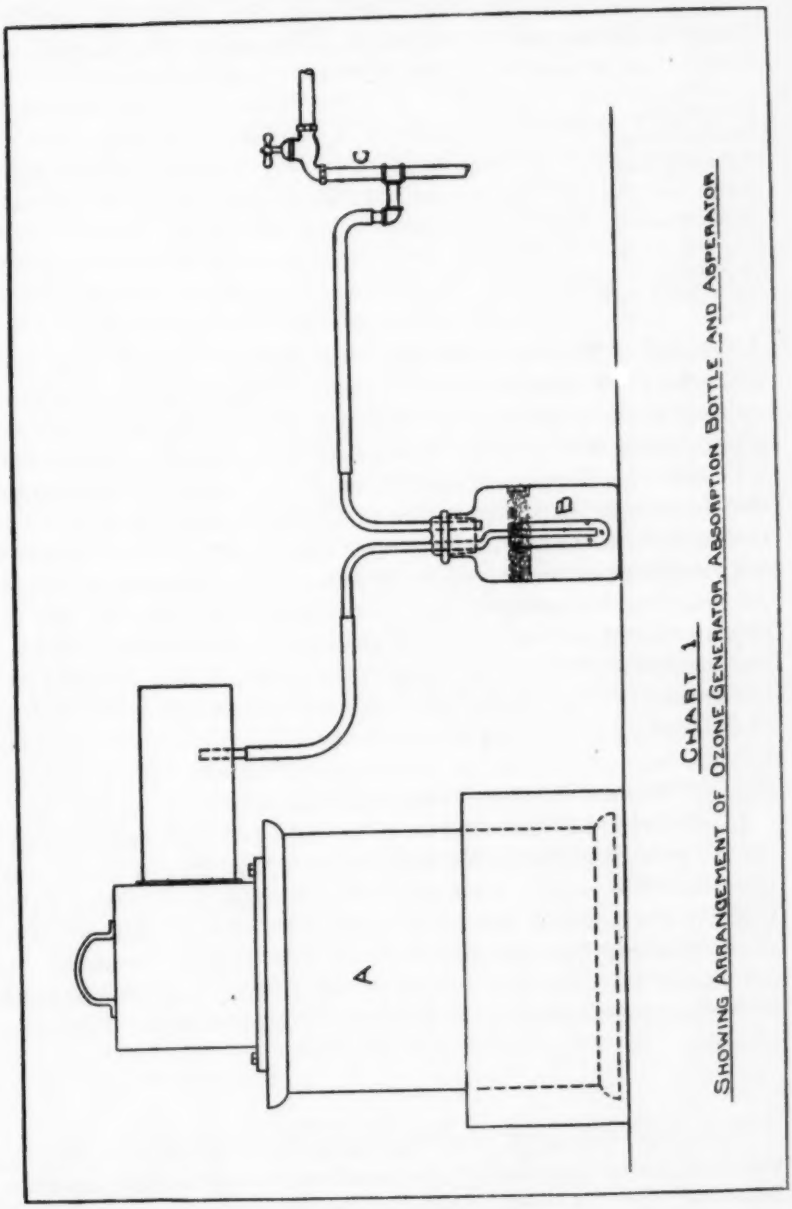


CHART 1

SHOWING ARRANGEMENT OF OZONE GENERATOR, ABSORPTION BOTTLE AND ASPERATOR

TABLE I

Average percentage removal of micro-organisms effected by the ozonization plant of the Baltimore County Water and Electric Company

	per cent
Diatomaceae	48.0
Cyanophyceae	55.0
Chlorophyceae	64.0
Fungi	46.2
Protozoa	41.5
Rotifera	32.8
Crustacea	30.0
Amorphous matter	41.0

Samples of swamp water were ozonized for one-half hour and then examined microscopically. There appeared to be a general disintegration of all the organisms containing chlorophyll and excepting where these growths were massed in bunches they were killed. The chlorophyll was scattered through the water but apparently the ozone had but a slight, if any, bleaching effect upon it. The diatoma, crustacea and protozoa were unaffected. After ozonization the samples were set aside for twenty-four hours and again examined. By this time the crustacea and protozoa were all dead but not removed; the color of the water had increased and there was a decided increase in the odor. The killing of the crustacea was probably due not to the oxidizing effect of the ozone but on account of the removal of the food supply by sterilization of the water. The color and odor increase was caused by the scattering of the chlorophyll and oil globules through the water when the organisms were broken up.

In support of this theory of the color increase a weak gasoline solution of pure chlorophyll was made up and through this ozone was passed for five hours. Even after this long period of contact there was not the slightest reduction in the color of the solution. The same concentration of ozone in twenty minutes removed 75 per cent of the color in a sample of water which had been stained by boiling a quantity of dead leaves in distilled water and then filtering.

ODORS

There has been much discussion recently in reference to the removal of odors by ozonization, but practically all of the investigations have been directed to the elimination of malodorous compounds that exist in the atmosphere so that the removal of odors in solution

touches a somewhat different phase of the subject. An attempt was made in this investigation to determine the general effect of ozonization in reference to odor removal from water, particularly those odors arising from algae growths. It was demonstrated from the tests that where the ozone acted upon the water containing living micro-organisms the characteristic odors were intensified. This condition was due to oxidation and disintegration of the plant and scattering the oil globules through the solution. These oily substances were only acted upon after complete oxidation of the organic matter present. In view of this fact waters containing micro-organisms were first filtered before attempting to deodorize them with ozone. At the time of conducting these tests it was not possible to obtain samples of water giving all the characteristic odors of the various forms of algae growths, but a number of substances that impart a distinctive odor were mixed with samples of tap water and the deodorizing effect of the ozone was noted. The data obtained from the tests, although they do not give any positive evidence of the ability of ozone to remove all odors arising from micro-organisms, gives some idea of the value of the gas as a deodorizer for water impregnated with such objectionable substances.

1. A distinctive algae odor arising from a sample of stagnant swamp water was greatly reduced in ten minutes with an ozone concentration of 0.20 gram per cubic meter and completely removed in thirty minutes. The same odor was entirely eliminated by a concentration of 1.69[1] grams in one minute.

2. A faint fishy odor caused by algae growths was removed in ten minutes with a concentration of 0.18 gram of the ozone gas.

3. Oil of rose dissolved in water imparting a distinct odor to the samples was but little affected after ten minutes of ozonization with a concentration of 0.20 gram, but almost entirely removed in thirty minutes of continuous ozonization at this same concentration. A concentration of 1.69 grams removed the odor in ten minutes.

4. Essence of heliotrope was acted upon in about the same manner as oil of rose, excepting that it was somewhat more easily removed by the high concentration.

[1] Where concentrations greater than 0.20 gram are reported they were obtained from the Herring Run ozonizers. It is possible with the generators at Herring Run to obtain concentrations as high as 5 grams per cubic meter. Concentrations higher than this are not economical as the ozone is not all used in passing through the sterilizers.

5. A few drops of oil of cloves in a half liter bottle was apparently unaffected by ozone at 0.20 concentration after one-half hour continuous contact. A concentration of 1.69 turned the samples a deep yellow and then red. The odor was greatly intensified during the first few minutes but lost its characteristic odor and imparted a very disagreeable woody odor to the solution.

6. Oil of wintergreen acted similarly to oil of cloves but did not lose its characteristic odor even in one-half hour using a concentration of 1.69 grams of ozone.

7. Oil of peppermint acted as did wintergreen, not being reduced in one-half hour of continuous ozonization. It was noted also that the ozone caused a bluish smoke to be generated when acting upon the peppermint, similar to the effect of this gas upon turpentine.

8. Mercaptan in dilutions of approximately one to one million was unaffected, showing no material reduction in the intensity of the odor arising from it.

9. Skatol in dilutions of 1 to 500,000 was not reduced with one concentration of 0.20 gram in thirty minutes. Higher concentrations were not employed.

10. Fecal odors from greatly diluted bacterial cultures were not reduced with concentrations of 0.20 gram. Higher concentrations were not tried.

11. The odor from oil of violets dissolved in water was slightly reduced in ten minutes with a concentration of 0.20 and entirely removed in thirty minutes. Ozone concentrations of 1.69 removed it in ten minutes.

12. A solution of tannic acid was greatly increased in color and odor by two minutes' ozonization and a concentration of 0.20 gram of the gas. This condition is one of considerable importance as it demonstrates one of the serious difficulties of color removal encountered in the operation of ozone sterilization.

CONCLUSION

The observations that have been made demonstrate clearly that certain forms of algae are very readily removed from water by direct oxidation while certain other forms are entirely unaffected even with protracted periods of contact with the ozone. In addition to this it has been noted that there is an increase in the odor arising from direct ozonization of algae that can only be removed after complete oxidation of the organic content of the water.

As has previously been stated, these studies were undertaken not with the idea of making use of ozone as an algaecide but to determine what influence such growths would have in maintaining the efficiency of the sterilization plant, and to this extent the experiments have been of considerable value.

At practically all ozone water sterilization plants abroad the raw water supplies are filtered previous to treatment so that the influence of algae upon the efficiencies of the systems has not been studied. As the rate of filtration used at all these places is about the same as employed by mechanical filters in this country it is reasonable to suppose that practically all of the organisms are removed by the filter beds, but there is a possibility of the growth of organisms in the underdrains and conduits of the system, the presence of which will reduce the efficiency of sterilization in proportion to their abundance.

The ability of ozone to remove or reduce certain odors arising from substances dissolved in water is to the mind of the writer one of great importance. There is no doubt that ozone is a powerful deodorizing gas under certain conditions and when brought into direct contact with the substance for a sufficient period. Its deodorizing value depends on the oxidizability of the substance treated, and concentration of the gas as well as the thoroughness of the mix.